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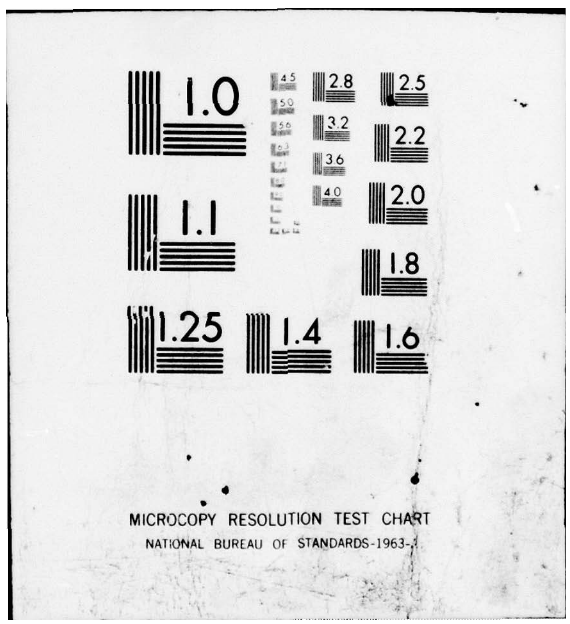
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ESTIMATES FOR HYDRAULIC EFFICIENCY AND BLADE CHARACTERISTICS FOR PRELIMINARY PUMPJET DESIGN EXERCISE.

(10) W. S. Gearhart ~~and~~ J. E. Fredley

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Subject: Estimates for Hydraulic Efficiency and Blade Characteristics for Preliminary Pumpjet Design Exercise

References: See page 20

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Acknowledgment: The work reported in this document was sponsored by the Naval Sea Systems Command, Code 63R (formerly 035).

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Nomenclature

Letter Symbols

$\overline{H}$	the pressure head placed into the fluid, ft
J	the advance ratio based on body diameter, nondimensional
K	an inlet energy loss coefficient, nondimensional
P	the static pressure, lb/ft^2
P_∞	the free static pressure corresponding to the given submergence dept, lb/ft^2
P_v	the fluid vapor pressure at its bulk temperature, lb/ft^2
r_T	the rotor tip radius, ft
r_B	the maximum body radius of the vehicle, ft
S/C	the space-to-chord ratio, nondimensional
$\overline{U}$	the average peripheral blade velocity based on mass flow, ft/sec
$\overline{V}_m$	the average fluid meridional velocity component based on mass flow, ft/sec
$\Delta\overline{V}$	the average fluid velocity change between stations 1 and 7 based on mass flow, ft/sec
$\overline{V}_\theta$	the average fluid peripheral velocity component based on mass flow, ft/sec
$\overline{V}$	the average absolute fluid velocity based on mass flow, ft/sec
V_∞	the vehicle forward velocity, ft/sec

Greek Letters

α	the absolute fluid angle, radians
β	the relative fluid angle, radians
ρ	the fluid density, $slug/ft^3$
σ	the cavitation index, nondimensional

Nomenclature (Continued)

Subscripts

1, 2, ... 7	indicates station location
m	indicates a mean value
R	indicates pertaining to the rotor
S	indicates pertaining to the stator

INTRODUCTION

The following outlines a method for determining the blade space-to-chord ratio to provide a prescribed blade cavitation index. It also indicates the hydraulic efficiency that would be obtained as a function of the advance ratio and the ingested mass flow of the pumpjet. This procedure has been added to the preliminary design process described in [1]*, which in the past, has assumed the hydraulic efficiency at some constant value typical of axial flow pumps. As a first check, the Akron propulsor of [1] is reviewed to see if the procedure can be applied with reasonable results. In addition, a series of runs were made for a body having a drag coefficient of 0.103 and at a number of advance ratios for both a preswirl and conventional pumpjet.

ESTIMATES OF EFFICIENCY AND BLADE CHARACTERISTICS FOR A CONVENTIONAL PUMPJET

The efficiency of a stage of an axial flow compressor is presented in [2] and shall be used as a basis to predict the efficiency of the pumpjet based on section characteristics of the rotor and stator blading at the mean radius, r_m. The conventional pumpjet geometry is decribed in Figure 1. In the preliminary design phase a very limited knowledge of the flow field characteristics and blade section parameters are known and, therefore, it is necessary to make some engineering approximations.

It is first necessary to obtain the space-to-chord ratio, or its inverse solidity, needed to satisfy the limits of cavitation that are desired. A conservative estimate is made that the static pressure forward of the rotor blade tip, P_2, is equal to the free-stream static pressure, P_∞.

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On this basis, the rotor blade pressure coefficient at cavitation inception, C_{b_R}, becomes

$$C_{b_R} = \frac{P_2 - P_v}{\frac{\rho W_2^{\,2}}{2}} = \frac{P_\infty - P_v}{\frac{\rho W_1^{\,2}}{2}} = \sigma_R \left(\frac{V_\infty}{W_2}\right)^2 \quad . \tag{1}$$

The value of (W_2/V_∞) is the relative velocity ratio approaching the rotor blade at the $(0.9\ r_T/r_B)$ radius and is defined by Equation (6). The impulse momentum relation can be used to approximate the average differnce in static pressure across the blade as outlined in [1]:

$$\frac{\overline{\Delta p}}{\frac{\rho V_\infty^{\,2}}{2}} = 2 \left(\frac{S}{C}\right)_R \left(\frac{W_2}{\overline{V}_{m_2}}\right) \left(\frac{\overline{V}_{m_2}}{V_\infty}\right) \left(\frac{\Delta\overline{V}_{\theta_R}}{V_\infty}\right) \quad . \tag{2}$$

A review of a number of blade pressure diagrams has indicated the average pressure difference across a blade chord closely approximates the difference in pressure from blade inlet to the minimum pressure point on the blade. On this basis,

$$C_{b_R} = \frac{\overline{\Delta p}}{\frac{\rho V_\infty^{\,2}}{2}} \left(\frac{V_\infty}{W_2}\right)^2 = 2 \left(\frac{S}{C}\right)_R \left(\frac{V_\infty}{W_2}\right) \left(\frac{\Delta\overline{V}_{\theta_R}}{V_\infty}\right) \quad . \tag{3}$$

The value of $\Delta\overline{V}_{\theta_R}/V_\infty$ for any ingested mass flow can be evaluated from:

$$\frac{\overline{H}}{\frac{V_\infty^{\,2}}{2g}} = \left[2 \left(\frac{\overline{\Delta V}}{V_\infty}\right) \left(\frac{\overline{V}_{m_2}}{V_\infty}\right) + \left(\frac{\overline{\Delta V}}{V_\infty}\right)^2 + K \left(\frac{\overline{V}_{m_1}}{V_\infty}\right)^2 \right] = 2 \left(\frac{\overline{U}}{V_\infty}\right) \left(\frac{\Delta\overline{V}_{\theta_R}}{V_\infty}\right) \quad , \tag{4}$$

where all the quantities in the brackets are tabulated on the output of the preliminary pumpjet design program (PPDP) of [3]. The value $(\Delta\overline{V}_{\theta_R}/V_\infty)$ is confined to an upper limit of $(\overline{U}/V_\infty)$.

The quantity $\overline{U}/V_\infty$ can be expressed as:

$$\frac{\overline{U}}{V_\infty} = (0.9\ \frac{\pi}{J}) \left(\frac{r_T}{r_B}\right) \quad , \tag{5}$$

where r_T/r_B is computed in the (PPDP) for each mass flow. The value of (W_2/V_∞) can be estimated as:

$$\frac{W_2}{V_\infty} = \left[\left(\frac{\overline{U}}{V_\infty}\right)^2 + \left(\frac{\overline{V}_{m_2}}{V_\infty}\right)^2\right]^{\frac{1}{2}} \quad . \tag{6}$$

The preceding provides the necessary data to determine (S/C) from Equation (3) that satisfy cavitation requirements. An upper limit of 1.8 is placed on this quantity.

The estimate of blade drag is obtained as outlined in [2] and consists of increments due to profile and secondary flow drag. The annulus wall drag is not included since this has already been considered in the shroud surface skin friction drag with was added to the required propulsor thrust as indicated in [1].

The rotor blade drag is then:

$$C_{D_R} = C_{D_P} + C_{D_S} \quad , \tag{7}$$

and

$$C_{D_P} = \text{blade profile drag} = 0.020 - 0.004 \left(\frac{S}{C}\right)_R \quad ;$$

$$C_{D_S} = \text{secondary flow drag} = 0.018\ {C_L}_R^{\,2} \quad .$$

The value of the rotor lift coefficient C_{L_R} can be evaluated as:

$$C_{L_R} = 2 \left(\frac{\Delta \overline{V}_{\theta_R}}{W_2} \right) \left(\frac{S}{C} \right)_R \quad . \tag{8}$$

The total pressure loss coefficient through the rotor blade row can now be determined as outlined in [2] where:

$$\zeta_R = \frac{\Delta P_T}{\left(\frac{\rho W_2^{\,2}}{2} \right)_{loss}} = C_{D_R} \left(\frac{C}{S} \right)_R \frac{\cos^2 \beta_2}{\cos^3 \beta_m} \quad . \tag{9}$$

The values of β_2 and β_m in Equation (9) are estimated for the rotor in the following manner:

$$\tan \beta_2 = \left(\frac{\overline{U}}{V_\infty} \right) \left(\frac{V_\infty}{\overline{V}_{m_2}} \right) \quad ,$$

$$\tan \beta_3 = \left(\frac{\overline{U}}{V_\infty} - \frac{\overline{V}_{\theta_3}}{V_\infty} \right) \left(\frac{V_\infty}{1.15\ \overline{V}_{m_2}} \right) \quad ,$$

and

$$\tan \beta_m = \frac{1}{2} (\tan \beta_2 + \tan \beta_3) \quad .$$

It is assumed in the above that the meridional velocity accelerates by a factor of 1.15 in passing through the rotor. The preceding provides an estimate of total pressure loss through the rotor blade row and now it is necessary to perform a similar analysis for the stator.

The stator blade drag and solidity can be similarly evaluated, where in this case the stator is located behind the rotor. The relation for the average pressure difference over the stator blade is: (The subscript 4 denotes a station at the stator leading edge.)

$$\frac{\overline{\Delta P}}{\frac{\rho V_\infty^2}{2}} = 2 \left(\frac{S}{C}\right)_S \left(\frac{\overline{V}_4}{\overline{V}_{m_4}}\right)\left(\frac{\overline{V}_{m_4}}{V_\infty}\right)\left(\frac{\Delta\overline{V}_{\theta_S}}{V_\infty}\right) \tag{10}$$

where it shall be assumed that:

$$\frac{\overline{V}_{m_4}}{V_\infty} = 1.2 \frac{\overline{V}_{m_1}}{V_\infty} \quad ,$$

$$\frac{\overline{V}_{\theta_4}}{V_\infty} = 1.1 \frac{\overline{V}_{\theta_3}}{V_\infty} \quad ,$$

and

$$\frac{\overline{V}_4}{V_\infty} = \left[\left(\frac{\overline{V}_{\theta_4}}{V_\infty}\right)^2 + \left(\frac{\overline{V}_{m_4}}{V_\infty}\right)^2\right]^{\frac{1}{2}} \quad .$$

It is necessary to now relate Equation (10) to the cavitation index of the stator blade system. This can be approximated by writing the energy relation between far upstream of the pumpjet and the stator blade inlet:

$$P_\infty + \rho \frac{\overline{V}_{m_1}^2}{2} = P_4 + \rho \frac{\overline{V}_{m_4}^2}{2} + \rho \frac{\overline{V}_{\theta_4}^2}{2} - g\overline{H} \quad . \tag{11}$$

The quantity (P_v) can be subtracted from each side of Equation (11) and the relation rearranged to give:

$$\sigma_S = C_{b_S}\left(\frac{\bar{V}_4}{V_\infty}\right)^2 + \left(\frac{\bar{V}_{m_3}}{V_\infty}\right)^2 - \left(\frac{\bar{V}_{m_1}}{V_\infty}\right)^2 + \left(\frac{\bar{V}_{\theta_4}}{V_\infty}\right)^2 - \frac{\bar{H}}{\frac{V_\infty^2}{2g}} \quad . \tag{12}$$

The quantity C_{b_S} is now expressed as,

$$C_{b_S} = 2\left(\frac{S}{C}\right)_S \left(\frac{V_\infty}{V_4}\right)\left(\frac{V_{\theta_4}}{V_\infty}\right)$$

and can be substituted into Equation (12) to give:

$$\left(\frac{S}{C}\right)_S = \left[\sigma_S - \left(\frac{\bar{V}_{m_4}}{V_\infty}\right)^2 + \left(\frac{\bar{V}_{m_1}}{V_\infty}\right)^2 - \left(\frac{\bar{V}_{\theta_4}}{V_\infty}\right)^2 + \frac{\bar{H}}{\frac{V_\infty^2}{2g}}\right]\frac{1}{2}\left(\frac{V_\infty}{\bar{V}_{\theta_4}}\right)\left(\frac{V_\infty}{V_4}\right) \quad . \tag{13}$$

The cavitation index substituted in Equation (13) is that value calculated in the program for the rotor at the mass flow coefficient considered and assumes no acceleration or deceleration of the flow as it approaches the rotor. An upper limit for the space-to-chord ratio of 2.0 has been imposed on the output. The stator blade drag can be estimated where:

$$C_D = C_{D_P} + C_{D_S} \quad , \tag{14}$$

where

$$C_{D_P} = 0.020 - 0.004\left(\frac{S}{C}\right)_S \quad ,$$

and

$$C_{D_S} = 0.018\, C_{L_S}^{\,2} \quad .$$

For the stator assume:

$$C_{L_S} = 2 \left(\frac{S}{C}\right)_S \left(\frac{\Delta\overline{V}_{\theta_S}}{V_4}\right) . \tag{15}$$

The total pressure loss coefficient for the stator is then:

$$\zeta_S = \left(\frac{\Delta P_T}{\frac{\rho\overline{V}_4^{\,2}}{2}}\right) = C_D \left(\frac{C}{S}\right)_S \frac{\cos^2\alpha_4}{\cos^3\alpha_m} , \tag{16}$$

where:

$$\tan\alpha_4 = \frac{1.1\ \frac{\overline{V}_{\theta_3}}{V_\infty}}{1.2\ \frac{\overline{V}_{m_1}}{V_\infty}} ;$$

$$\tan\alpha_5 = 0.0 ;$$

and

$$\tan\alpha_m = \frac{1}{2}\tan\alpha_4 .$$

The hydraulic efficiency is then computed as:

$$\eta_H = 1 - \left\{\frac{\zeta_R + \zeta_S \left(\frac{\overline{V}_3}{\overline{W}_2}\right)}{\frac{\overline{H}}{\frac{V_\infty^{\,2}}{2g}} \left(\frac{V_\infty}{\overline{W}_2}\right)^2}\right\} . \tag{17}$$

The preceding shall be applied to the pumpjet designed in [1] to determine efficiency, lift coefficient, etc., as determined by this technique and compared to that obtained in the Akron exercise at the selected design point.

Appendix (I) lists the input data for the Akron pumpjet analysis and the new program. The output is also listed and consists of an output identical to that of [3] plus the output which indicates computed hydraulic efficiency, the rotor and stator space-to-chord, and their respective lift coefficients. The use of the rotor lift coefficient in conjunction with Figure 2, which is an empirical correlation of lift coefficient and achievable blade pressure coefficient, will aid in selecting the optimum rotor tip diameter. The estimated hydraulic efficiency for the Akron pumpjet in [1] was 0.89, which closely agrees with that computed and listed as EFF-TOT in Appendix (I) at a r_T/r_B of 0.414. The lift coefficient of the rotor and stator is listed in Appendix (I) as 0.34 and 1.02 respectively. The values computed in [1] for the rotor and stator near the 0.9 r_T are 0.3 and 1.0.

ESTIMATES OF EFFICIENCY AND BLADE CHARACTERISTICS FOR A PRESWIRL PUMPJET

As depicted in Figure 3, this pumpjet arrangement would consist of a stator system upstream of a rotor. The stator places swirl in the flow counter to rotor rotation. In the case of the stator vanes, since the velocity over their surfaces is relatively low, the blade solidity is a function of blade loading rather than cavitation performance. On this basis, the upper limit of lift coefficient for the stators is assumed at 1.4. The output from the PPDP provides data to compute $\Delta\overline{V}_{\theta_S}/V_\infty$ for each mass flow from:

$$\Delta\overline{V}_{\theta_S}/V_\infty = \frac{\left[2\left(\frac{\Delta\overline{V}}{V_\infty}\right)\left(\frac{\overline{V}_{m_2}}{V_\infty}\right) + \left(\frac{\Delta\overline{V}}{V_\infty}\right)^2 + K\left(\frac{\overline{V}_{m_1}}{V_\infty}\right)^2\right]}{(2)\ (0.9)\left(\frac{\pi}{J}\right)\left(\frac{r_T}{r_B}\right)} \quad . \tag{18}$$

An upper limit has been imposed on $\overline{V}_{\theta_3}/V_\infty$ so as not to permit it to exceed the blade speed at 0.9 r_T/r_B.

The relation for the lift coefficient permits computing $(S/C)_S$, assuming the relative velocity ratio over the stator blade surface $(\overline{V}_2/V_\infty)$ is unity.

$$\left(\frac{S}{C}\right)_S = \left(\frac{C_{L_S}}{2}\right)\left(\frac{\frac{\overline{V}_2}{V_\infty}}{\frac{\overline{V}_{\theta_3}}{V_\infty}}\right) = \frac{0.7}{\frac{\overline{V}_{\theta_3}}{V_\infty}} \quad . \tag{19}$$

At the larger values of ingested mass the values of $(S/C)_S$ will be greater than 2.0. However, an upper limit of 2.0 has been imposed on this quantity. The preceding provides data to compute the profile and secondary drag coefficients for the stator. The profile drag coefficient for the preswirl stator blade row is lower than that estimated for the stator of the conventional pumpjet because it is in an assumed uniform flow field that enters the blade row at zero incidence. On this basis, the drag coefficient is lower as indicated by [4].

$$C_D = C_{D_P} + C_{D_S} \quad ,$$

where:

$$C_{D_P} = 0.012 - 0.004\left(\frac{S}{C}\right)_S \quad ;$$

$$C_{D_S} = 0.018\ C_{L_S}^{\,2} \quad .$$

The angles α_2 and α_m are approximated for inclusion in Equation (16) to compute the total pressure loss coefficient through the stator as:

$$\alpha_2 = 0 \; ; \; \tan\alpha_3 = \frac{\dfrac{\bar{V}_{\theta_3}}{V_\infty}}{\dfrac{\bar{V}_{m_3}}{V_\infty}} \; ; \; \tan\alpha_m = \frac{1}{2}\tan\alpha_3 \quad .$$

The rotor solidity shall be estimated assuming that the relative velocity near the blade tip is:

$$\left(\frac{W_4}{V_\infty}\right)^2 = \left[\left(0.9\,\frac{\pi}{J}\,\frac{r_T}{r_B}\right) + \left(\frac{\bar{V}_{\theta_4}}{V_\infty}\right)\right]^2 + \left(\frac{\bar{V}_{m_4}}{V_\infty}\right)^2 \quad . \tag{20}$$

The value of $\bar{V}_{\theta_4}/V_\infty$ is the same as computed for insertion in Equation (19).

The energy equation from upstream of the preswirl vanes to the inlet of the rotor, assuming the same meridional velocity at both stations can be expressed:

$$P_\infty = P_4 + \rho\,\frac{\bar{V}_{\theta_4}^{\,2}}{2} \quad . \tag{21}$$

By subtracting vapor pressire (P_v) from both sides of Equation (21) and using the relation given by Equation (3) the value of $(S/C)_R$ can be written as:

$$\left(\frac{S}{C}\right)_R = \frac{\sigma_R - \left(\dfrac{\bar{V}_{\theta_4}}{V_\infty}\right)^2}{2\,\dfrac{\bar{V}_{\theta_4}}{V_\infty}\left(\dfrac{W_4}{V_\infty}\right)} \quad . \tag{22}$$

It is assumed that zero acceleration or deceleration of the flow, from upstream to the rotor inlet, occurs when computing (σ_R) for insertion in Equation (22). On this basis, the energy equation can be written between these two stations and, using the relations for the minimum pressure coefficient, the cavitation index at rotor inlet is computed as:

$$\sigma_R = C_{b_R} \left(\frac{W_4}{V_\infty}\right)^2 + \left(\frac{\bar{V}_{\theta_4}}{V_\infty}\right)^2 + K \left(\frac{\bar{V}_{m_4}}{V_\infty}\right)^2 \quad . \tag{23}$$

An upper limit was placed on the above $(S/C)_R$ value of 1.8. The lift coefficient for both the stator and rotor is estimated based on the relation:

$$C_{L_S} = 2 \left(\frac{S}{C}\right)_S \left(\frac{\Delta\bar{V}_{\theta_S}}{V_\infty}\right) \qquad \text{(for stator)} \quad ,$$

$$C_{L_R} = 2 \left(\frac{S}{C}\right)_R \left(\frac{\Delta\bar{V}_{\theta_R}}{W_4}\right) \qquad \text{(for rotor)} \quad ,$$

where the respective (S/C) of stator and rotor are inserted.

The values of β_4 and β_m can be estimated for evaluation of Equation (9) by the following:

$$\tan \beta_4 = \frac{0.9 \, \frac{\pi}{J} \, \frac{r_T}{r_B} + \frac{\bar{V}_{\theta_4}}{V_\infty}}{\frac{\bar{V}_{m_4}}{V_\infty}} \; ; \; \tan \beta_5 = \frac{0.9 \, \frac{\pi}{J} \, \frac{r_T}{r_B}}{1.25 \, \frac{\bar{V}_{m_4}}{V_\infty}} \; ; \; \tan \beta_m = \frac{1}{2} \left(\tan \beta_4 + \beta_5\right)$$

where:

$$\left(\frac{W_4}{V_\infty}\right)^2 = \left(0.9\,\frac{\pi}{J}\,\frac{r_T}{r_B} + \frac{\overline{V}_{\theta_4}}{V_\infty}\right)^2 + \left(\frac{\overline{V}_{m_4}}{V_\infty}\right)^2 .$$

The preceding values are used to compute the drag coefficient of the preswirl rotor as:

$$C_{D_R} = C_{D_P} + C_{D_S} ,$$

where

$$C_{D_P} = 0.020 - 0.004 \left(\frac{S}{C}\right)_R ,$$

and

$$C_{S_S} = 0.018\, C_{L_R}^{\;2} .$$

The preceding quantities are then used to compute the total pressure loss coefficient indicated by Equation (9). The hydraulic efficiency of this preswirl stage is expressed as:

$$\eta_H = 1 - \left\{ \frac{\zeta_R + \zeta_S \left(\dfrac{\overline{V}_2}{W_4}\right)^2}{\left(\dfrac{\overline{H}}{\dfrac{V_\infty^{\,2}}{2g}}\right)\left(\dfrac{V_\infty}{W_4}\right)^2} \right\} . \qquad (24)$$

A flow diagram of the preliminary design procedure is outlined in Appendix (II) for both the conventional and preswirl pumpjet configurations.

A sample problem has been run for the preswirl pumpjet configuration and the conventional pumpjet. The input data and a listing of the program and output are shown in Appendix (III) for both types of pumpjets at advance ratios of 0.675, 0.844, and 1.125. The power requirements that would be obtained assuming a hydraulic efficiency of 88 percent versus that obtained from the described methods are plotted in Figure 4 for the conventional pumpjet and Figure 5 for the preswirl pumpjet. It is apparent from these plots that the optimum tip diameter and the efficiency varies with advance ratio for both types of pumpjets.

The preswirl and conventional pumpjet are approximately equal in efficiency for a given advance ratio. The efficiency of either type of pumpjet tends to decrease at low values of advance ratio. This loss in efficiency is associated with higher blade surface velocities due to the higher shaft speeds at the lower advance ratios.

SUMMARY

The results of the preliminary design procedure described within provides data indicating the hydraulic efficiency and power requirements of a pumpjet operating on a given body at a specified advance ratio as a function of ingested mass flow. The space-to-chord ratio and lift coefficient of the blading near the tip (0.9 r_T/r_B) is computed and can be used in selecting blade chord, if blade number is known. The lift coefficient has been empirically correlated with achievable minimum blade pressure coefficients as indicated by Figure 2. This correlation in combination with the program output provides a guide in selecting the mass flow and lift coefficient that will provide the desired cavitation performance.

The results of the described preliminary design procedure indicates that the maximum efficiency and the associated mass flow and tip radius of the pumpjet changes as a function of advance ratio. This is contrasted to past preliminary design procedures which assumed the hydraulic efficiency constant as a function of ingested mass flow.

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3. Treaster, A. L., "Computerization of the Preliminary Pumpjet Design Procedure," ARL/PSU Technical Memorandum, File No. 506-04, March 20, 1970.

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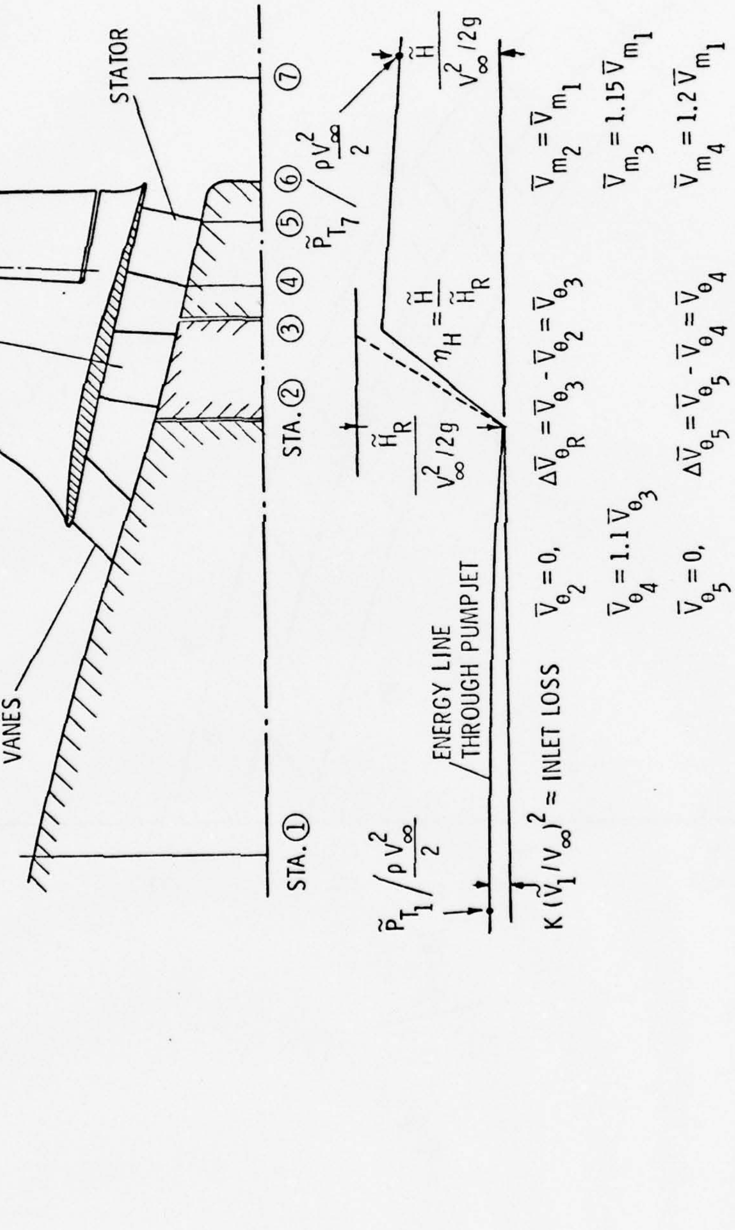


Figure 1. Conventional Pumpjet Geometry and Energy Distribution

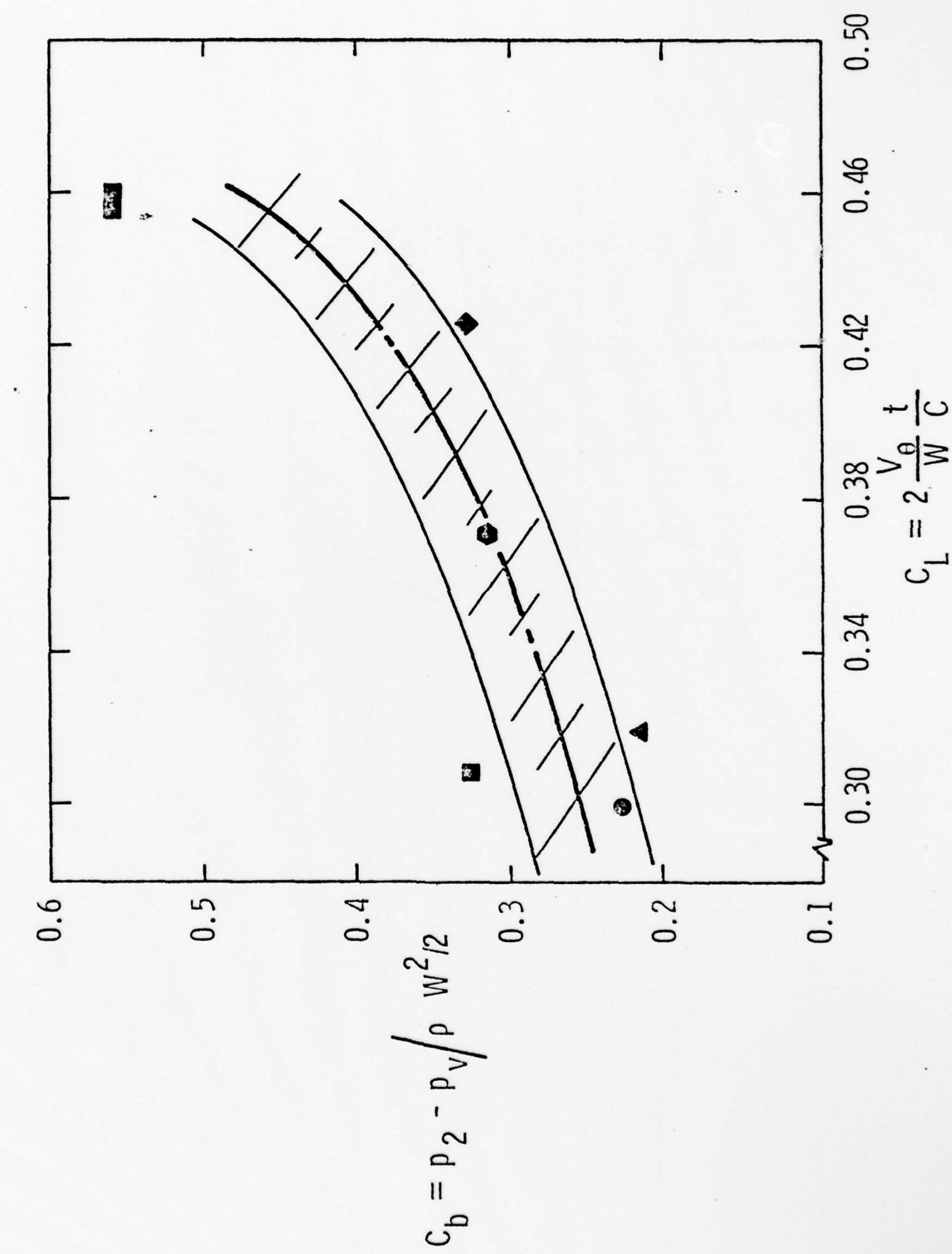


Figure 2. Experimental Minimum Pressure Coefficient of the Leakage Vortex Versus Blade Tip Lift Coefficient

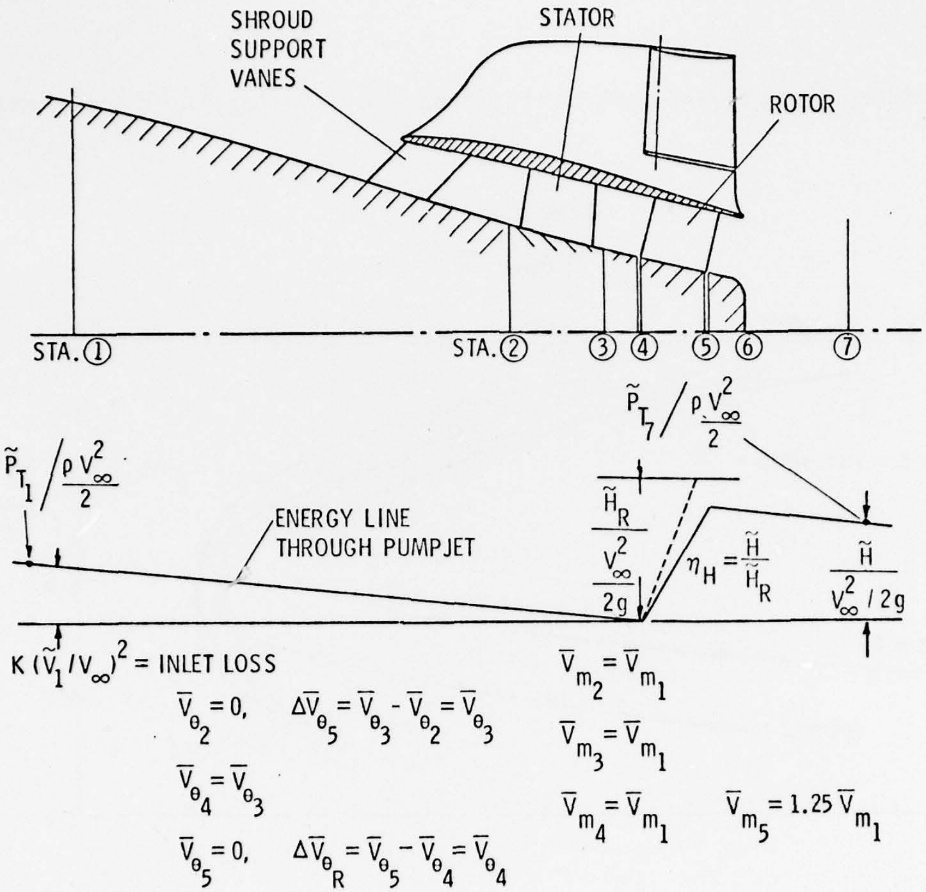


Figure 3. Preswirl Pumpjet Geometry and Energy Distribution

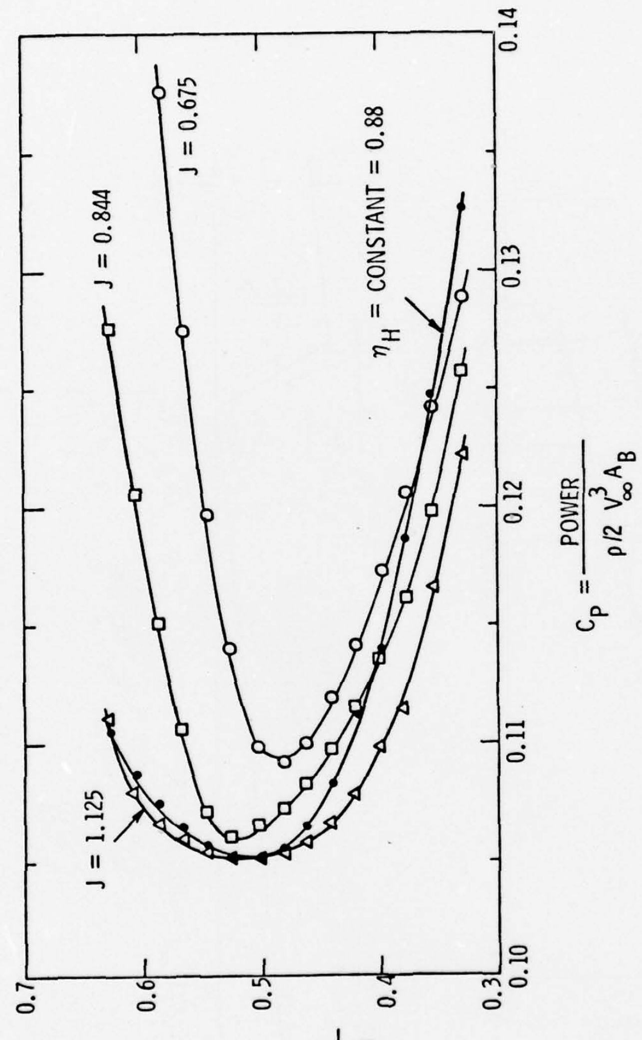


Figure 4. r_T/r_B Versus Power Coefficient for Conventional Pumpjet

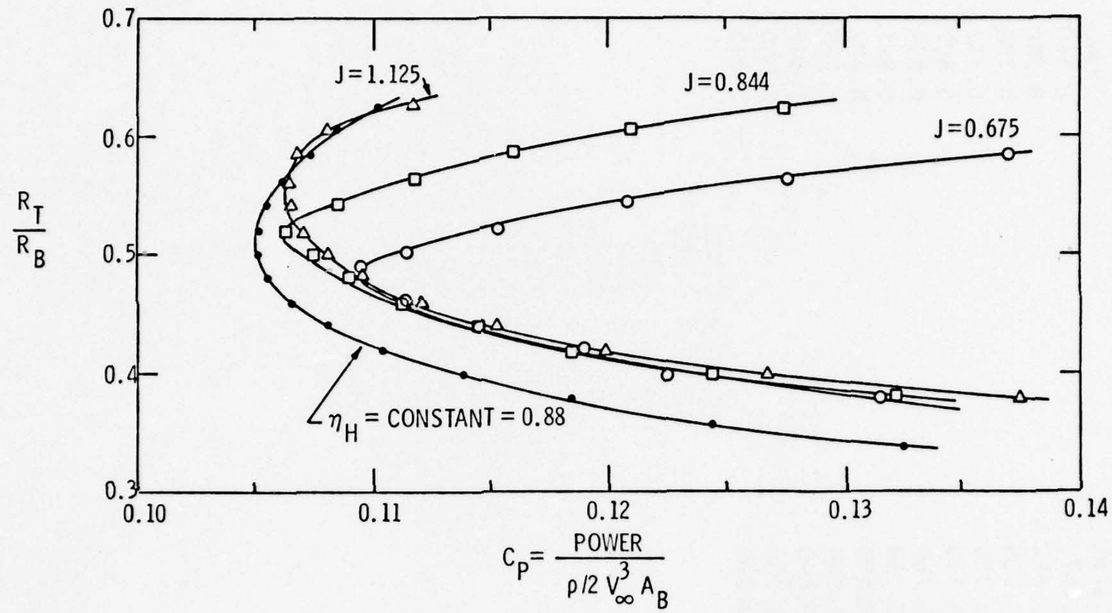


Figure 5. r_T/r_B Versus Power Coefficient for Preswirl Pumpjet

Appendix I

AKRON input data

$N = 12$

R/RB	V/V_∞
0.677	0.540
0.692	0.700
0.708	0.790
0.724	0.852
0.740	0.897
0.760	0.938
0.780	0.965
0.800	0.982
0.830	0.998
0.860	1.000
0.900	1.000
0.940	1.000

CDBB = 0.052
CDS = 0.003
V1OV2 = 1.15
ETAH = 0.89
PHI = 0.175
LORB = 1.00
RH1 = 0.677
RH2 = 0.250
XXK = 0.13
PRCNT = 0.0
CB = 0.3
PHI2 = 0.262
NN = 1.0
ADRAT = 1.0

THE LOSS COEFFICIENT, K, IS 0.13000

R/R0	V/VREF	A/A0	FMASS	CT	VBAR/VREF	DELV/VREF	CP	VMOM/VREF	VENG/VREF
0.67700	0.54100	0.00000	0.00000	0.05500					
0.68225	0.60157	0.00725	0.00415	0.05519	0.57095	6.74043	0.24783	0.57262	0.57345
0.68752	0.65066	0.01453	0.00875	0.05537	0.60273	3.19503	0.13895	0.60365	0.60510
0.69278	0.71957	0.02185	0.01395	0.05555	0.62551	2.00076	0.10408	0.64221	0.64560
0.69804	0.76244	0.02733	0.01959	0.05571	0.66675	1.42464	0.08366	0.67588	0.68025
0.70330	0.78857	0.03575	0.02541	0.05587	0.68826	1.10066	0.08066	0.69920	0.70378
0.70856	0.80422	0.04441	0.03141	0.05603	0.70730	0.89278	0.07603	0.71761	0.72223
0.71382	0.82108	0.05200	0.03758	0.05619	0.72269	0.74810	0.07324	0.73324	0.73787
0.71908	0.83722	0.05966	0.04393	0.05633	0.73535	0.64168	0.07157	0.74711	0.75177
0.72434	0.85263	0.06737	0.05044	0.05647	0.74878	0.56020	0.07064	0.75976	0.76446
0.72960	0.86727	0.07513	0.05712	0.05661	0.76028	0.49589	0.07022	0.77148	0.77624
0.73486	0.88114	0.08295	0.06395	0.05675	0.77102	0.44388	0.07018	0.78247	0.78731
0.74012	0.89421	0.09084	0.07095	0.05688	0.78114	0.40102	0.07043	0.79285	0.79778
0.74538	0.90646	0.09877	0.07810	0.05701	0.79072	0.36512	0.07090	0.80269	0.80771
0.75064	0.91785	0.10676	0.08539	0.05714	0.79981	0.33465	0.07155	0.81204	0.81715
0.75590	0.92839	0.11481	0.09282	0.05727	0.80845	0.30850	0.07234	0.82093	0.82614
0.76116	0.93804	0.12291	0.10038	0.05739	0.81668	0.28584	0.07325	0.82940	0.83469
0.76642	0.94679	0.13107	0.10807	0.05751	0.82451	0.26604	0.07426	0.83744	0.84231
0.77168	0.95460	0.13929	0.11588	0.05763	0.83195	0.24860	0.07535	0.84508	0.85052
0.77694	0.96145	0.14755	0.12381	0.05775	0.83902	0.23315	0.07651	0.85231	0.85791
0.78220	0.96735	0.15589	0.13184	0.05787	0.84572	0.21939	0.07773	0.85914	0.86468
0.78746	0.97235	0.16427	0.13997	0.05798	0.85206	0.20705	0.07899	0.86557	0.87114
0.79272	0.97649	0.17271	0.14819	0.05810	0.85804	0.19595	0.08029	0.87162	0.87720
0.79798	0.98058	0.18121	0.15651	0.05821	0.86370	0.18591	0.08163	0.87730	0.88288
0.80324	0.98423	0.18976	0.16491	0.05832	0.86905	0.17679	0.08299	0.88265	0.88822
0.80850	0.98758	0.19837	0.17340	0.05843	0.87412	0.16848	0.08438	0.88772	0.89325
0.81376	0.99086	0.20704	0.18197	0.05854	0.87894	0.16086	0.08580	0.89250	0.89801
0.81902	0.99367	0.21576	0.19063	0.05865	0.88352	0.15395	0.08723	0.89703	0.90250
0.82428	0.99604	0.22454	0.19936	0.05875	0.88787	0.14741	0.08869	0.90132	0.90674
0.82954	0.99787	0.23337	0.20817	0.05886	0.89200	0.14145	0.09016	0.90536	0.91074
0.83480	0.99911	0.24226	0.21704	0.05896	0.89591	0.13593	0.09165	0.90917	0.91449
0.84006	0.99983	0.25121	0.22599	0.05907	0.89960	0.13081	0.09314	0.91274	0.91801
0.84532	1.00016	0.26021	0.23499	0.05917	0.90307	0.12604	0.09465	0.91609	0.92128
0.85058	1.00021	0.26927	0.24405	0.05927	0.90634	0.12160	0.09615	0.91921	0.92433
0.85584	1.00011	0.27838	0.25317	0.05938	0.90941	0.11744	0.09766	0.92212	0.92717
0.86110	0.99997	0.28755	0.26234	0.05948	0.91230	0.11355	0.09917	0.92435	0.92981
0.86636	0.99983	0.29678	0.27156	0.05958	0.91503	0.10991	0.10069	0.92740	0.93228
0.87162	0.99974	0.30607	0.28085	0.05968	0.91760	0.10649	0.10221	0.92979	0.93459
0.87688	0.99983	0.31541	0.29013	0.05977	0.92003	0.10324	0.10374	0.93205	0.93676
0.88214	0.99995	0.32480	0.29958	0.05987	0.92234	0.10019	0.10527	0.93417	0.93881
0.88740	0.99989	0.33425	0.30903	0.05997	0.92454	0.09731	0.10680	0.93618	0.94073
0.89266	0.99994	0.34375	0.31854	0.06007	0.92662	0.09458	0.10835	0.93808	0.94255
0.89792	0.99978	0.35333	0.32810	0.06016	0.92861	0.09199	0.10989	0.93989	0.94428
0.90318	1.00002	0.36295	0.33772	0.06026	0.93050	0.08953	0.11145	0.94160	0.94591
0.90844	1.00004	0.37262	0.34740	0.06035	0.93230	0.08719	0.11301	0.94323	0.94746
0.91370	1.00005	0.38236	0.35713	0.06045	0.93403	0.08496	0.11457	0.94478	0.94893
0.91896	1.00005	0.39215	0.36692	0.06054	0.93568	0.08284	0.11615	0.94625	0.95033
0.92422	1.00005	0.40199	0.37677	0.06063	0.93725	0.08082	0.11772	0.94766	0.95166
0.92948	1.00003	0.41189	0.38667	0.06073	0.93876	0.07888	0.11931	0.94900	0.95293
0.93474	1.00002	0.42185	0.39663	0.06082	0.94021	0.07704	0.12090	0.95028	0.95414
0.94000	1.00000	0.43195	0.40664	0.06091	0.94160	0.07527	0.12250	0.95151	0.95530

May 3, 1979
WSG:JER:mmj

```
THE MINIMUM VALUE OF CP IS  0.0701597 THE CORRESPONDING AREA RATIO IS 0.0800346

AND THE MASS FLOW RATE COEFFICIENT IS 0.0613941

THE AREA RATIO IS INCREASED BY   0.00000PERCENT TO THE DESIGN VALUE  0.0800346

CP AND FMASS ARE 0.0701597 AND  0.0613941 RESPECTIVELY

THE ADVANCE RATIO IS    1.00000
 RI/RO         SIGMA
 0.3189435     2.95[illegible]9422
 0.3299725     2.0040512
 0.3414854     1.4391794
 0.3526225     1.0305902
 0.3634194     0.8419391
 0.3739026     0.6777433
 0.3841009     0.5522197
 0.3940353     0.4798207
 0.4037253     0.4207886
 0.4131330     0.3726673
 0.4224369     0.3491094
```

THE ADVANCE RATIO IS 1.00000

R/RB	CP-NEW	EFF-ROT	EFF-STAT	EFF-TOT	CL-STAT	CL-ROT	S/C-ROT	S/C-STAT	SGMA	RT/RS
0.68225	0.22115	0.79127	0.99872	0.99769	3.07701	0.34761	0.21332	2.00000	0.30941	0.26564
0.68752	0.12433	0.99569	0.99461	0.99032	3.03361	0.34739	0.21789	2.00000	0.34390	0.28052
0.69278	0.09437	0.98081	0.98725	0.97719	3.07519	0.34780	0.21869	2.00000	0.38204	0.29476
0.69804	0.08162	0.98150	0.98249	0.96431	2.13331	0.34796	0.21900	1.37301	0.41932	0.30844
0.70330	0.07552	0.97143	0.97947	0.95048	1.20578	0.34743	0.21797	0.78293	0.45239	0.32163
0.70856	0.07286	0.95769	0.96775	0.92875	0.72498	0.34665	0.21645	0.46798	0.48331	0.33440
0.71382	0.07154	0.94312	0.96106	0.91119	0.64235	0.34576	0.24166	0.43312	0.51301	0.34679
0.71908	0.07017	0.93956	0.96515	0.90775	0.82968	0.34485	0.30732	0.62230	0.54197	0.35884
0.72434	0.06962	0.93382	0.96801	0.90297	0.92275	0.34395	0.37367	0.79352	0.57045	0.37058
0.72960	0.06952	0.92763	0.96905	0.89893	0.98915	0.34307	0.45533	0.96130	0.59860	0.38204
0.73486	0.06972	0.92372	0.96990	0.89592	1.01649	0.34221	0.53596	1.11417	0.62651	0.39325
0.74012	0.07012	0.92083	0.97072	0.89387	1.02460	0.34139	0.62326	1.26027	0.65425	0.40422
0.74538	0.07069	0.91875	0.97154	0.89261	1.02193	0.34060	0.71394	1.40235	0.68187	0.41498
0.75064	0.07139	0.91737	0.97236	0.89202	1.01377	0.33984	0.80873	1.54261	0.70937	0.42554
0.75590	0.07213	0.91653	0.97319	0.89195	1.00328	0.33911	0.90739	1.68278	0.73679	0.43592
0.76116	0.07306	0.91615	0.97402	0.89245	0.99234	0.33840	1.00964	1.82415	0.76412	0.44612
0.76642	0.07460	0.91615	0.97485	0.89312	0.98199	0.33771	1.11529	1.96775	0.79139	0.45617
0.77168	0.07561	0.91650	0.97549	0.89404	0.92020	0.33705	1.22414	2.00000	0.81857	0.46606
0.77694	0.07608	0.91714	0.97591	0.89505	0.85234	0.33640	1.33593	2.00000	0.84569	0.47582
0.78220	0.07717	0.91803	0.97620	0.89619	0.79289	0.33577	1.45064	2.00000	0.87273	0.48544
0.78746	0.07834	0.91915	0.97636	0.89742	0.74051	0.33516	1.56797	2.00000	0.89969	0.49494
0.79272	0.07951	0.92047	0.97643	0.89877	0.69413	0.33456	1.68783	2.00000	0.92657	0.50432
0.79798	0.08075	0.92144	0.97642	0.89971	0.65233	0.33210	1.80000	2.00000	0.95340	0.51359
0.80324	0.08255	0.91638	0.97634	0.89470	0.61583	0.31018	1.80000	2.00000	0.98017	0.52276
0.80850	0.08444	0.91109	0.97621	0.88942	0.58267	0.29060	1.80000	2.00000	1.00690	0.53183
0.81376	0.08639	0.90559	0.97603	0.88389	0.55267	0.27304	1.80000	2.00000	1.03362	0.54080
0.81902	0.08841	0.89983	0.97582	0.87812	0.52548	0.25720	1.80000	2.00000	1.06033	0.54969
0.82428	0.09051	0.89397	0.97557	0.87213	0.50074	0.24287	1.80000	2.00000	1.08703	0.55848
0.82954	0.09267	0.88786	0.97530	0.86593	0.47815	0.22984	1.80000	2.00000	1.11372	0.56720
0.83480	0.09490	0.88156	0.97501	0.85952	0.45747	0.21796	1.80000	2.00000	1.14041	0.57584
0.84006	0.09717	0.87505	0.97470	0.85292	0.43847	0.20709	1.80000	2.00000	1.16709	0.58441
0.84532	0.09955	0.86837	0.97439	0.84612	0.42096	0.19711	1.80000	2.00000	1.19376	0.59290
0.85058	0.10197	0.86149	0.97405	0.83912	0.40479	0.18792	1.80000	2.00000	1.22044	0.60132
0.85584	0.10444	0.85441	0.97371	0.83194	0.38980	0.17943	1.80000	2.00000	1.24712	0.60968
0.86110	0.10704	0.84714	0.97336	0.82458	0.37589	0.17157	1.80000	2.00000	1.27381	0.61798
0.86636	0.10969	0.83968	0.97302	0.81703	0.36293	0.16427	1.80000	2.00000	1.30053	0.62622
0.87162	0.11240	0.83204	0.97267	0.80929	0.35084	0.15749	1.80000	2.00000	1.32729	0.63440
0.87688	0.11521	0.82420	0.97231	0.80139	0.33954	0.15116	1.80000	2.00000	1.35410	0.64252
0.88214	0.11810	0.81612	0.97195	0.79329	0.32894	0.14525	1.80000	2.00000	1.38095	0.65060
0.88740	0.12109	0.80776	0.97161	0.78502	0.31899	0.13972	1.80000	2.00000	1.40788	0.65861
0.89266	0.12417	0.79956	0.97125	0.77657	0.30963	0.13453	1.80000	2.00000	1.43486	0.66658
0.89792	0.12735	0.79097	0.97090	0.76795	0.30081	0.12966	1.80000	2.00000	1.46193	0.67451
0.90318	0.13066	0.78218	0.97055	0.75915	0.29248	0.12508	1.80000	2.00000	1.48907	0.68238
0.90844	0.13407	0.77321	0.97020	0.75017	0.28461	0.12076	1.80000	2.00000	1.51630	0.69021
0.91370	0.13761	0.76405	0.96985	0.74102	0.27716	0.11669	1.80000	2.00000	1.54361	0.69800
0.91896	0.14128	0.75470	0.96951	0.73169	0.27010	0.11284	1.80000	2.00000	1.57101	0.70575
0.92422	0.14509	0.74516	0.96917	0.72218	0.26339	0.10920	1.80000	2.00000	1.59851	0.71345
0.92948	0.14903	0.73542	0.96883	0.71250	0.25702	0.10576	1.80000	2.00000	1.62610	0.72112
0.93474	0.15314	0.72549	0.96849	0.70263	0.25096	0.10249	1.80000	2.00000	1.65380	0.72875
0.94000	0.15741	0.71537	0.96316	0.69259	0.24518	0.09939	1.80000	2.00000	1.68160	0.73634

Appendix II

Conventional Pumpjet Functional Diagram

SECTION ONE CALCULATIONS

↓

READ GEOMETRIC AND REFERENCE VELOCITY DATA, DRAG COEFFICIENTS AND ASSUMED HYDRAULIC EFFICIENCY

↓

SPLINE FIT THE REFERENCE VELOCITY PROFILE

↓

CALCULATE THE THRUST COEFFICIENT, MASS FLOW RATE COEFFICIENT, AND VARIOUS VELOCITY RATIOS AS A FUNCTION OF RADIAL DISTANCE AT THE REFERENCE STATION

↓

READ A VALUE OF LOSS COEFFICIENT

↓

CALCULATE PROPULSIVE COEFFICIENT AS A FUNCTION OF REFERENCE FLOW AREA AND ASSUMED HYDRAULIC EFFICIENCY

↓

WRITE OUTPUT DATA

↓

Proceed to Section Two Calculations

Conventional Pumpjet Functional Diagram

SECTION TWO CALCULATIONS

↓

READ PRCNT

↓

CALCULATE NEW VALUES OF PROPULSIVE COEFFICIENT AND MASS FLOW RATE COEFFICIENT FOR THE DESIGN INLET AREA RATIO

↓

CALCULATE THE ROTOR TIP RATIOS

↓

READ A VALUE OF ADVANCE RATIO

↓

CALCULATE CAVITATION INDEX AS A FUNCTION OF ADVANCE RATIO FOR EACH ROTOR TIP RATIO

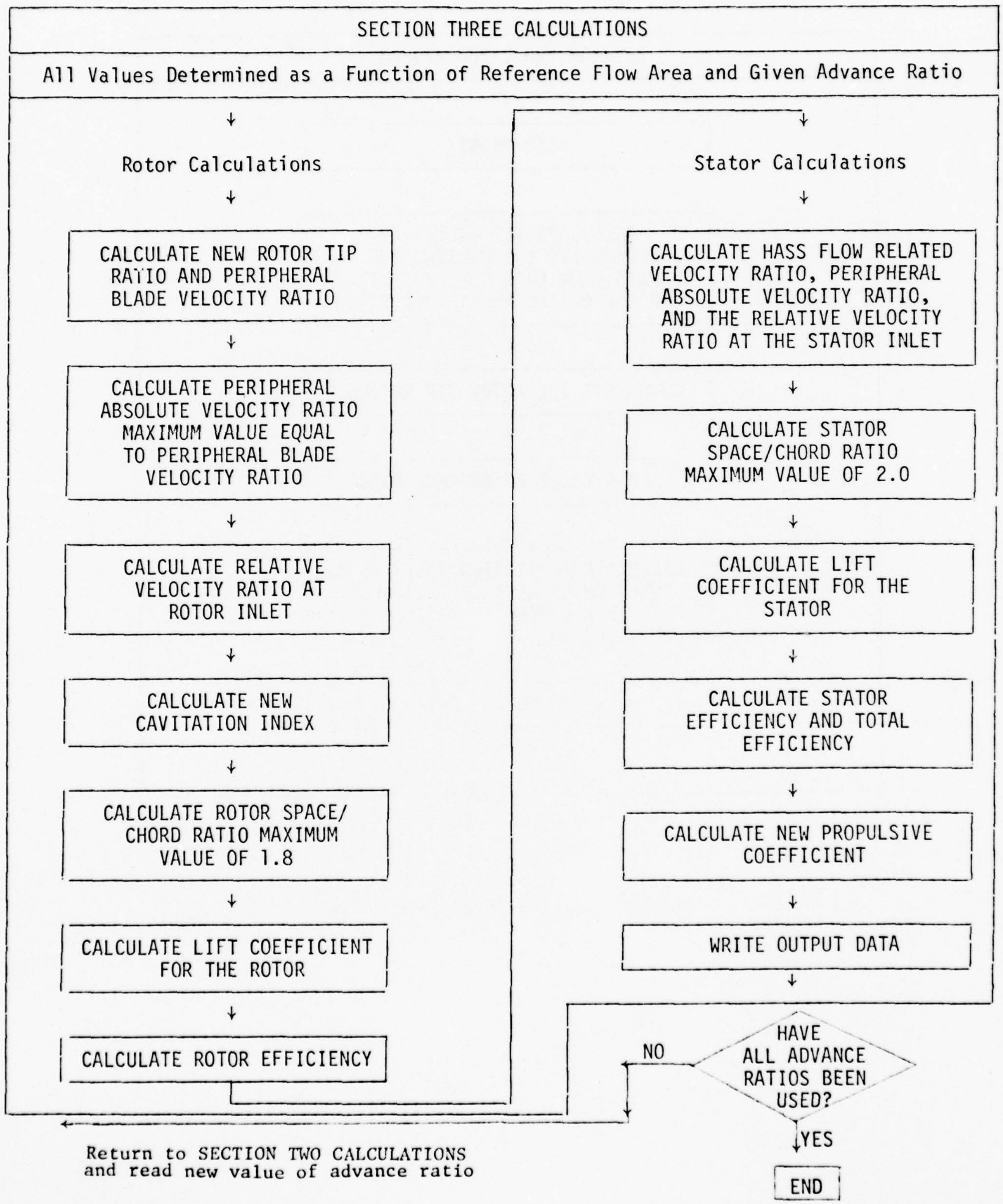
↓

WRITE OUTPUT DATA

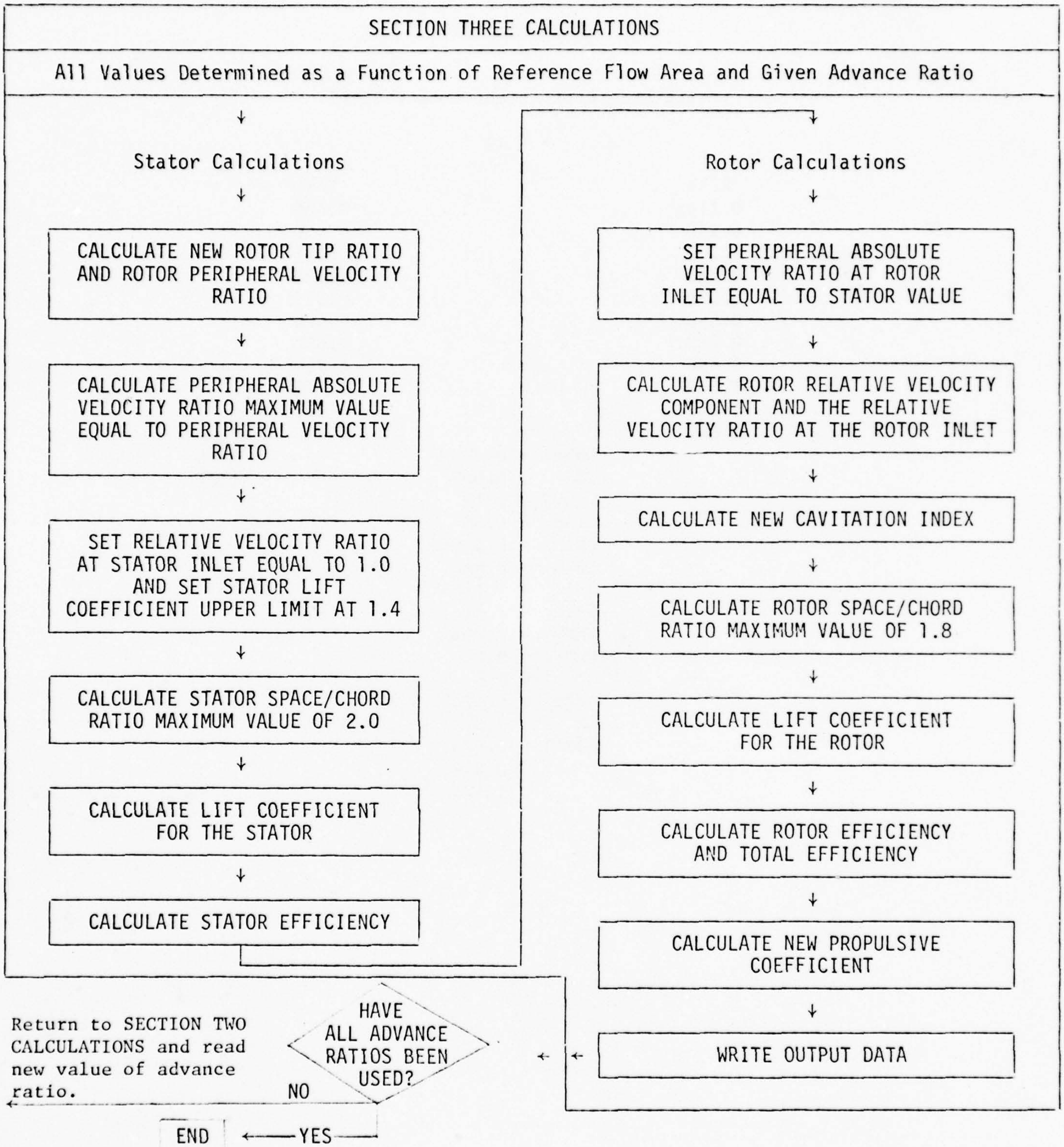
↓

Proceed to Section Three Calculations

Conventional Pumpjet Functional Diagram



Preswirl Pumpjet Functional Diagram



Appendix III

With Drag Coefficient CDBB = 0.103

N = 11

R/RB	V/V_∞
0.1188	0.430
0.150	0.450
0.200	0.485
0.250	0.528
0.300	0.575
0.350	0.628
0.400	0.680
0.450	0.730
0.500	0.775
0.550	0.818
0.600	0.860

CDBB = 0.103
CDS = 0.003
V1OV2 = 1.15
ETAH = 0.88
PHI = 0.1396
LORB = 0.662
RH1 = 0.1188
RH2 = 0.11
XXK = 0.08
PRCNT = 0.0
CB = 0.3
PHI2 = 0.174
NN = 3.0
ADRAT = 0.675, 0.844, 1.125

```
IBM SYSTEM/34 FORTRAN IV RELEASE 03                         PAGE 001    04/22/79   20:37

// READ DEVICE-SYSIN
// PRINT DEVICE-PPTR
*PROCESS MAP,LINK(R,LIB(JEFLIB)),SIZE(24)
    1          PROGRAM PROP
    2          REAL LORB,MSFLO
    3          DIMENSION AA(60),A(60),ADAR(60),A2DAR(60),B(60),C(60),CP(60)
    4          DIMENSION CPP(60),CT(60),DLTAV(60),EL(60),FFF(60),FF(60),F(60)
    5          DIMENSION FMASS(60),RR(60),R(60),RT(60),SC(60),SIGMA(60),VV(60)
    6          DIMENSION V(60),VBAR(60),VMOM(60),VENG(60),VVMOM(60),VVENG(60)
    7          DIMENSION CPPP(60),RTRR(60),CLS(60),CLP(60),SDCR(60),SDCS(60)
    8          DIMENSION EROT(60),ESTAT(60),ETOT(60),SGMA(60)
    9          EQUIVALENCE (A(1),VVMOM(1)),(B(1),VVENG(1))
         C
         C     THE PRELIMINARY PUMPJET DESIGN COMPUTER PROGRAM SELECTS AN
         C     OPTIMUM FLOW AREA FROM THE REFERENCE VELOCITY PROFILE BASED ON
         C     A MINIMUM VALUE OF PROPULSIVE COEFFICIENT.  FROM THESE DATA THE
         C     PROGRAM ALSO PREDICTS THE CAVITATION PERFORMANCE AS A FUNCTION
         C     OF ADVANCE RATIO AND ROTOR TIP DIAMETER.
         C     ADDITIONALLY, THE PROGRAM COMPUTES THE SPACE TO CHORD RATIO,
         C     LIFT COEFFICIENT, STAGE EFFICIENCY, AND TOTAL PUMPJET
         C     EFFICIENCY AS A FUNCTION OF INGESTED MASS FLOW AND ADVANCE RATIO.
         C
   10          READ(4,100)N
   11          DO 1 I=1,N
   12        1 READ(4,101)R(I),V(I)
   13          READ(4,101)CDBB,CDS,V1OV2,ETAH
   14          READ(4,101)PHI,LORB,RH1,RH2
   15          CALL SPEIT(N,R,V,SC,EL,A,B,C)
         C
         C     N IS THE NUMBER OF DATA POINTS DEFINING THE THE REFERENCE VELOCITY
         C     PROFILE
         C     R(I) AND V(I) ARE THE DATA POINTS DEFINING THE REFERENCE VELOCITY
         C     PROFILE
         C     CDBB IS THE BARE BODY DRAG COEFFICIENT
         C     CDS IS THE SKIN FRICTION DRAG COEFFICIENT
         C     V1OV2 IS A VELOCITY RATIO WHICH REPRESENTS THE ACCELERATION OF THE
         C     FLUID FROM THE REFERENCE STATION TO THE ROTOR DISK PLANE
         C     ETAH IS THE HYDRAULIC EFFICIENCY
         C     PHI IS THE LOCAL BODY ANGLE AT THE REFERENCE STATION WITH RESPECT
         C     TO THE VEHICLE CENTERLINE
         C     LORB IS THE NONDIMENSIONAL SHROUD LENGTH
         C     RH1 IS THE NONDIMENSIONAL BODY RADIUS AT THE REFERENCE STATION
         C     RH2 IS THE NONDIMENSIONAL BODY RADIUS AT THE ROTOR HUB
         C
   16          DLTAR=(R(N)-R(1))/50.0
   17          RR(1)=R(1)
   18          DO 2 I=2,51
   19        2 RR(I)=RR(I-1)+DLTAR
   20          DO 3 I=1,51
   21          CALL SPGET(N,R,V,SC,EL,RR(I),VV(I),YP,DP)
```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  22           CT(I)=1.0)*CD3B+4.0*CDS*LOPB*SORT(V1OV2*((RR(I))**2-RH1**2)+
              -RH2**2)
          C
          C    CT(I) IS THE REQUIRED THRUST COEFFICIENT
          C
  23         3 F(I)=2.0*RR(I)/COS(PHI)
  24           AOAB(1)=0.0
  25           DO 4 I=2,51
  26         4 AOAB(I)=AOAB(I-1)+0.5*(F(I)+F(I-1))*(RR(I)-RR(I-1))
          C
          C    AOAB(I) IS THE FLOW AREA AT THE REFERENCE STATION AS A FUNCTION OF
          C    P/P3
          C
  27           DO 5 I=1,51
  28           F(I)=2.0*(VV(I)*RR(I)/COS(PHI))
  29           FF(I)=VV(I)*F(I)
  30         5 FFF(I)=VV(I)*FF(I)
  31           FMASS(1)=0.0
  32           VVMOM(1)=0.0
  33           VVENG(1)=0.0
  34           DO 6 I=2,51
  35           FMASS(I)=FMASS(I-1)+0.5*(F(I)+F(I-1))*(RR(I)-RR(I-1))
  36           VVMOM(I)=VVMOM(I-1)+0.5*(FF(I)+FF(I-1))*(RR(I)-RR(I-1))
  37           VVENG(I)=VVENG(I-1)+0.5*(FFF(I)+FFF(I-1))*(RR(I)-RR(I-1))
  38           VBAR(I)=FMASS(I)/AOAB(I)
  39           VMOM(I)=VVMOM(I)/FMASS(I)
  40           VENG(I)=SQRT(VVENG(I)/FMASS(I))
  41         6 DLTAV(I)=0.5*(CT(I)/(COS(PHI)*AOAB(I)*VMOM(I)))
          C
          C    FMASS(I) IS THE MASS FLOW RATE COEFFICIENT
          C    VBAR(I) IS AN AVERAGE VELOCITY RATIO BASED ON MASS FLOW RATE
          C    VENG(I) IS AN AVERAGE VELOCITY RATIO BASED ON ENERGY
          C    DLTAV(I) IS THE NONDIMENSIONAL VELOCITY CHANGE BASED ON MOMENTUM
          C    VMOM(I) IS AN AVERAGE VELOCITY RATIO BASED ON MOMENTUM
          C
  42           READ(4,101)XXK
  43           WRITE(3,104)XXK
  44           WRITE(3,105)
          C
          C    XXK IS THE LOSS COEFFICIENT
          C
  45           WRITE(3,102)RR(1),VV(1),AOAB(1),FMASS(1),CT(1)
  46           DO 7 I=2,51
  47           CP(I)=(2.0*DLTAV(I)*VENG(I)+DLTAV(I)**2+XXK*VENG(I)**2)
              -*AOAB(I)*VBAR(I)/ETAH
  48         7 WRITE(3,102)RR(I),VV(I),AOAB(I),FMASS(I),CT(I),VBAR(I),DLTAV(I),
              -CP(I),VMOM(I),VENG(I)
          C
          C    THE FOLLOWING STATEMENTS (THROUGH 12) LOCATE THE POINT OF
          C    MINIMUM PROPULSIVE COEFFICIENT
          C
```

```
      DO 9 I=1,48
      CPP(I)=CP(I+3)
    9 AA(I)=ADAB(I+3)
      CALL SPFIT(48,AA,CPP,SC,EL,A,B,C)
      AINC=ADAB(51)/1000.0
      AAA=ADAB(4)
      CALL SPGET(48,AA,CPP,SC,EL,AAA,Y,YD,YDP)
      AQ=AAA
      YQ=Y
      DO 11 I=1,1000
      AAA=AAA+AINC
      CALL SPGET(48,AA,CPP,SC,EL,AAA,Y,YD,YDP)
      IF(Y-YQ)10,12,12
   10 AQ=AAA
      YQ=Y
   11 CONTINUE
   12 AMIN1=0.5*(AQ+AAA)
      READ(4,101)PRCNT
      AMIN2=(1.0+PRCNT)*AMIN1
C
C     AMIN1 IS THE FLOW AREA AT THE REFERENCE STATION CORRESPONDING TO
C     THE POINT OF MINIMUM PROPULSIVE COEFFICIENT
C     PRCNT IS THE AMOUNT BY WHICH THE DESIGNER INCREASES AMIN1 TO AMIN2
C     AMIN2 IS THE DESIGN VALUE OF THE FLOW AREA AT THE REFERENCE
C     STATION
C
      CALL SPGET(48,AA,CPP,SC,EL,AMIN1,Y1,YP,YDP)
      CALL SPGET(48,AA,CPP,SC,EL,AMIN2,Y2,YP,YDP)
      CALL SPFIT(51,ADAB,FMASS,SC,EL,A,B,C)
      CALL SPGET(51,ADAB,FMASS,SC,EL,AMIN1,Y3,YP,YDP)
      CALL SPGET(51,ADAB,FMASS,SC,EL,AMIN2,Y4,YP,YDP)
      WRITE(3,111)Y1,AMIN1,Y3
      P=100.0*PRCNT
      WRITE(3,112)P,AMIN2,Y2,Y4
      VENG(1)=0.0
      CALL SPFIT(51,ADAB,VENG,SC,EL,A,B,C)
      CALL SPGET(51,ADAB,VENG,SC,EL,AMIN2,Y5,YP,YDP)
      MSFLO=AMIN2*Y5
C
C     MSFLO IS A MASS FLOW RATE COEFFICIENT BASED ON VENG(I)
C     RT(I) IS THE NONDIMENSIONAL ROTOR TIP RADIUS
C     SIGMA(I) IS THE CAVITATION INDEX
C
      AINC2=AMIN2/10.0
      A2DAB(1)=AMIN2/2.0
      READ(4,101)CB,PHI2
C
C     CB IS AN ASSUMED VALUE OF THE MINIMUM PRESSURE COEFFICIENT OF THE
C     BLADE TIP SECTION
C     PH2 IS THE LOCAL FLOW ANGLE AT THE ROTOR HUB IN RADIANS
C
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            RT(1)=SQRT(A2OAB(1)*COS(PHI2)+RH2**2)
            DO 13 I=2,11
            A2OAB(I)=A2OAB(I-1)+AINC2
         13 RT(I)=SQRT(A2OAB(I)*COS(PHI2)+RH2**2)
            READ(4,100)NN
            DO 22 J=1,NN
            READ(4,101)ADRAT
            IF(J.NE.1)GO TO 14
            WRITE(3,106)ADRAT
            GO TO 15
         14 WRITE(3,114)ADRAT
         15 WRITE(3,107)
            DO 16 I=1,11
            SIGMA(I)=CB*(MSFLO**2/(A2OAB(I)**2)+((3.1416/ADRAT)**2)*RT(I)**2)+
           -MSFLO**2*(1.0/(A2OAB(I)**2)-(1.0-XXK)/(AMIN2**2))
         16 WRITE(3,108)RT(I),SIGMA(I)
      C
            WRITE(3,114)ADRAT
            WRITE(3,115)
            DO 21 I=2,51
      C
      C     ROTOR APPLICATION
      C
            HBAR=2.*DLTAV(I)*VBAR(I)+DLTAV(I)**2+XXK*VBAR(I)**2
            RTRB(I)=SQRT(ADAB(I)*V1OV2*COS(PHI2)+RH2**2)
            UBAR=0.9*3.1416*RTRB(I)/ADRAT
            VTHV=HBAR/(2.*UBAR)
            IF(VTHV.LE.UBAR) GO TO 17
            VTHV=UBAR
         17 CONTINUE
            W1OV=SQRT(UBAR**2+VBAR(I)**2)
            SOMA(I)=CB*W1OV**2+XXK*VBAR(I)**2
            SOCR(I)=SOMA(I)/(2.*W1OV*VTHV)
            IF(SOCR(I).LT.1.8) GO TO 18
            SOCR(I)=1.8
         18 CONTINUE
            CLR(I)=2.*VTHV*SOCR(I)/W1OV
            CDPR=0.02-0.004*SOCR(I)
            CDSR=0.018*CLR(I)**2
            CDR=CDPR+CDSR
            ALP1R=ATAN(UBAR/VBAR(I))
            CA1R=COS(ALP1R)
            ALP2R=ATAN((UBAR-VTHV)/(V1OV2*VBAR(I)))
            TN1=SIN(ALP1R)/COS(ALP1R)
            TN2=SIN(ALP2R)/COS(ALP2R)
            ALPMR=ATAN((TN1+TN2)/2.)
            CAMR=COS(ALPMR)
            PLOSR=CDR*CA1R**2/(SOCR(I)*CAMR**3)
            EROT(I)=1.-PLOSR*W1OV**2/HBAR
      C
      C     STATOR APPLICATION
```

```
      C
            VBAR3=1.2*VBAR(I)
            VTHV3=1.1*VTHV
            W3OV=SQRT(VTHV3**2+VBAR3**2)
            SOCS(I)=(SGMA(I)-VBAR3**2+VBAR(I)**2-VTHV3**2+HBAR)/(2.*VTHV3*W3OV
           -)
            IF(SOCS(I).LT.2.) GO TO 19
            SOCS(I)=2.
         19 CONTINUE
            CLS(I)=2.*SOCS(I)*VTHV3/W3OV
            CDPS=0.02-0.004*SOCS(I)
            CDSS=0.018*CLS(I)**2
            CDS=CDPS+CDSS
            ALP1S=ATAN(VTHV3/VBAR3)
            CA1S=COS(ALP1S)
            ALPMS=ATAN(0.5*SIN(ALP1S)/COS(ALP1S))
            CAMS=COS(ALPMS)
            PLOSS=CDS*CA1S**2/(SOCS(I)*CAMS**3)
            ESTAT(I)=1.-PLOSS*W3OV**2/HBAR
            ETOT(I)=EROT(I)*ESTAT(I)
            CPPP(I)=CP(I)*ETAH/ETOT(I)
         21 WRITE(3,110)RR(I),CPPP(I),EROT(I),ESTAT(I),ETOT(I),CLS(I),CLR(I),
           -SOCR(I),SOCS(I),SGMA(I),RTRB(I)
         22 CONTINUE
      C
      C     HBAR IS THE NONDIMENSIONAL EXPRESSION FOR THE ENERGY
      C     PLACED IN THE FLUID
      C     UBAR IS AN AVERAGE PERIPHERAL BLADE VELOCITY RATIO
      C     RTRB(I) IS THE NONDIMENSIONAL ROTOR TIP RADIUS
      C     VTHV IS AN AVERAGE PERIPHERAL ABSOLUTE VELOCITY RATIO
      C     AT THE ROTOR LEADING EDGE
      C     W1OV IS AN AVERAGE RELATIVE VELOCITY RATIO AT THE
      C     ROTOR LEADING EDGE
      C     SOCR(I) IS THE BLADE SPACING TO CHORD RATIO FOR THE ROTOR
      C     CLR(I) IS THE ROTOR LIFT COEFFICIENT
      C     CDPR IS THE ROTOR PROFILE DRAG COEFFICIENT
      C     CDSR IS THE ROTOR SECONDARY FLOW DRAG COEFFICIENT
      C     CDR IS THE ROTOR DRAG COEFFICIENT
      C     EROT(I) IS THE ROTOR HYDRAULIC EFFICIENCY
      C     PLOSR IS THE PRESSURE LOSS THROUGH THE ROTOR
      C     VBAR3 IS AN AVERAGE VELOCITY RATIO AT THE STATOR INLET
      C     VTHV3 IS AN AVERAGE PERIPHERAL ABSOLUTE VELOCITY RATIO
      C     AT THE STATOR INLET
      C     W3OV IS AN AVERAGE RELATIVE VELOCITY RATIO AT THE STATOR INLET
      C     SOCS(I) IS THE BLADE SPACING TO CHORD RATIO FOR THE STATOR
      C     CLS(I) IS THE STATOR LIFT COEFFICIENT
      C     CDPS IS THE STATOR PROFILE DRAG COEFFICIENT
      C     CDSS IS THE STATOR SECONDARY FLOW DRAG COEFFICIENT
      C     CDS IS THE STATOR DRAG COEFFICIENT
      C     PLOSS IS THE PRESSURE LOSS THROUGH THE STATOR
      C     ESTAT(I) IS THE STATOR HYDRAULIC EFFICIENCY
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          C      EIOT(I) IS THE TOTAL PUMPJET HYDRAULIC EFFICIENCY
          C      CPPP(I) IS THE PROPULSIVE COEFFICIENT AS A FUNCTION
          C      OF CALCULATED TOTAL EFF. VS ASSUMED TOTAL EFF.
          C      SGMA(I) IS THE CAVITATION INDEX FOR A GIVEN MASS FLOW
          C
   148      100 FORMAT(I5)
   149      101 FORMAT(4F10.5)
   150      102 FORMAT(' ',10(F8.5,4X))
   151      104 FORMAT('1','THE LOSS COEFFICIENT, K, IS',F10.5)
   152      105 FORMAT(' ',1X,'R/RB',8X,'V/VREF',6X,'A/AB',8X,'FMASS',7X,'CT'
               -,9X,'VBAR/VREF',3X,'DELV/VREF',4X,'CP',9X,'VMOM/VREF',2X,
               -'VENG/VREF')
   153      106 FORMAT('0','THE ADVANCE RATIO IS',F10.5)
   154      107 FORMAT(' ',' RT/RB',7X,'SIGMA')
   155      108 FORMAT(' ',2(F10.7,3X))
   156      110 FORMAT(' ',10(F8.5,3X),F8.5)
   157      111 FORMAT('1','THE MINIMUM VALUE OF CP IS ',F10.7,' THE CORRESPONDING
               - AREA RATIO IS',F10.7,//' AND THE MASS FLOW RATE COEFFICIENT IS',
               -F10.7)
   158      112 FORMAT('0','THE AREA RATIO IS INCREASED BY',F10.5,'PERCENT TO THE
               -DESIGN VALUE ',F10.7,//' CP AND FMASS ARE',F10.7,' AND ',F10.7,
               -' RESPECTIVELY')
   159      114 FORMAT('1','THE ADVANCE RATIO IS',F10.5)
   160      115 FORMAT(' ',1X,'R/RB',7X,'CP-NEW',5X,'EFF-ROT',3X,'EFF-STAT',4X,'EF
               -F-TOT',4X,'CL-STAT',4X,'CL-ROT',5X,'S/C-ROT',3X,'S/C-STAT',4X,'SGM
               -A',7X,'RT/RB')
          C
   161             CALL EXIT
   162             END
```

VARIABLE ALLOCATION MAP

NAME	AT	HEX1	DEC1	HEX2	DEC2	NAME	AT	HEX1	DEC1	HEX2	DEC2
LJRB	R	01A2	00429			MSFLO	R	01B1	00433		
AA	R	01B5	00437	02A4	00676	ADAB	R	02A5	00677	0394	00916
A2DAB	R	0395	00917	0484	01156	C	R	0485	01157	0574	01396
CP	R	0575	01397	0664	01636	CPP	R	0665	01637	0754	01876
CT	R	0755	01877	0844	02116	DLTAV	R	0845	02117	0934	02356
EL	R	0935	02357	0A24	02596	FFF	R	0A25	02597	0B14	02836
FF	R	0B15	02837	0C04	03076	F	R	0C05	03077	0CF4	03316
FMASS	R	0CF5	03317	0DE4	03556	RR	R	0DE5	03557	0ED4	03796
R	R	0ED5	03797	0FC4	04036	RT	R	0FC5	04037	10B4	04276
SC	R	10B5	04277	11A4	04516	SIGMA	R	11A5	04517	1294	04756
VV	R	1295	04757	1384	04996	V	R	1385	04997	1474	05236
VBAR	R	1475	05237	1564	05476	VMOM	R	1565	05477	1654	05716
VENG	R	1655	05717	1744	05956	CPPP	R	1745	05957	1834	06196
RTRB	R	1835	06197	1924	06436	CLS	R	1925	06437	1A14	06676
CLR	R	1A15	06677	1B04	06916	SOCR	R	1B05	06917	1BF4	07156
SOCS	R	1BF5	07157	1CE4	07396	EROT	R	1CE5	07397	1DD4	07636
ESTAT	R	1DD5	07637	1EC4	07876	ETOT	R	1EC5	07877	1FB4	08116

THE LOSS COEFFICIENT, K, IS 0.08000

R/RB	V/VREF	A/AB	FMASS	CT	VPAR/VREF	DELV/VREF	CP	VMOM/VREF	VENG/VREF
0.11880	0.43000	0.00000	0.00000	0.10387					
0.12842	0.43613	0.00240	0.00104	0.10397	0.43319	50.43454	3.06011	0.43321	0.43322
0.13805	0.44227	0.00493	0.00218	0.10406	0.43637	24.11546	1.49183	0.43641	0.43643
0.14767	0.44849	0.00777	0.00342	0.10415	0.43963	15.39349	0.97232	0.43971	0.43975
0.15730	0.45476	0.01073	0.00475	0.10424	0.44297	11.06691	0.71478	0.44310	0.44316
0.16692	0.46116	0.01389	0.00620	0.10433	0.44639	8.49567	0.56189	0.44657	0.44668
0.17654	0.46774	0.01722	0.00775	0.10441	0.44991	6.80000	0.46120	0.45019	0.45032
0.18617	0.47458	0.02075	0.00941	0.10450	0.45354	5.60299	0.39026	0.45391	0.45409
0.19577	0.48175	0.02446	0.01119	0.10459	0.45729	4.71637	0.33785	0.45778	0.45802
0.20542	0.48930	0.02836	0.01308	0.10467	0.46113	4.03566	0.29773	0.46181	0.46212
0.21504	0.49723	0.03244	0.01509	0.10476	0.46523	3.49832	0.26519	0.46603	0.46642
0.22466	0.50545	0.03672	0.01724	0.10484	0.46945	3.06472	0.24086	0.47043	0.47092
0.23429	0.51391	0.04118	0.01951	0.10493	0.47381	2.70856	0.22018	0.47502	0.47562
0.24391	0.52251	0.04583	0.02192	0.10501	0.47833	2.41167	0.20306	0.47978	0.48050
0.25354	0.53119	0.05066	0.02447	0.10510	0.48296	2.16114	0.18873	0.48469	0.48555
0.26316	0.53993	0.05563	0.02716	0.10518	0.48772	1.94753	0.17663	0.48974	0.49074
0.27278	0.54878	0.06089	0.02999	0.10527	0.49257	1.76373	0.16633	0.49492	0.49608
0.28241	0.55781	0.06629	0.03298	0.10535	0.49752	1.60429	0.15751	0.50021	0.50154
0.29203	0.56709	0.07187	0.03612	0.10543	0.50257	1.46497	0.14992	0.50564	0.50714
0.30165	0.57667	0.07764	0.03942	0.10552	0.50772	1.34243	0.14335	0.51119	0.51288
0.31128	0.58659	0.08359	0.04288	0.10560	0.51300	1.23399	0.13765	0.51639	0.51879
0.32090	0.59675	0.08974	0.04652	0.10569	0.51839	1.13754	0.13269	0.52275	0.52486
0.33053	0.60707	0.09607	0.05033	0.10577	0.52390	1.05134	0.12838	0.52875	0.53110
0.34015	0.61744	0.10259	0.05432	0.10585	0.52952	0.97400	0.12462	0.53489	0.53749
0.34977	0.62776	0.10929	0.05850	0.10594	0.53523	0.90436	0.12135	0.54116	0.54402
0.35940	0.63796	0.11618	0.06286	0.10602	0.54103	0.84148	0.11851	0.54753	0.55065
0.36902	0.64804	0.12326	0.06741	0.10610	0.54689	0.78452	0.11605	0.55399	0.55739
0.37865	0.65803	0.13053	0.07216	0.10618	0.55280	0.73281	0.11392	0.56051	0.56413
0.38827	0.66796	0.13798	0.07710	0.10627	0.55875	0.68572	0.11209	0.56703	0.57104
0.39789	0.67784	0.14562	0.08224	0.10635	0.56475	0.64274	0.11054	0.57371	0.57794
0.40752	0.68770	0.15345	0.08758	0.10643	0.57077	0.60343	0.10922	0.58037	0.58489
0.41714	0.69752	0.16146	0.09314	0.10652	0.57682	0.56739	0.10812	0.58706	0.59187
0.42677	0.70724	0.16967	0.09890	0.10660	0.58289	0.53425	0.10721	0.59379	0.59887
0.43639	0.71681	0.17805	0.10497	0.10668	0.58898	0.50376	0.10649	0.60053	0.60539
0.44601	0.72619	0.18663	0.11105	0.10677	0.59507	0.47564	0.10593	0.60727	0.61291
0.45564	0.73532	0.19539	0.11746	0.10685	0.60116	0.44963	0.10551	0.61401	0.61992
0.46526	0.74421	0.20434	0.12403	0.10693	0.60723	0.42566	0.10523	0.62072	0.62690
0.47489	0.75290	0.21348	0.13092	0.10701	0.61328	0.40341	0.10508	0.62740	0.63384
0.48451	0.76145	0.22280	0.13793	0.10710	0.61930	0.38278	0.10504	0.63405	0.64073
0.49413	0.76989	0.23231	0.14527	0.10718	0.62530	0.36360	0.10510	0.64065	0.64757
0.50376	0.77827	0.24201	0.15277	0.10726	0.63126	0.34576	0.10526	0.64721	0.65437
0.51338	0.78661	0.25190	0.16051	0.10734	0.63720	0.32913	0.10551	0.65373	0.66111
0.52301	0.79492	0.26197	0.16847	0.10743	0.64310	0.31361	0.10585	0.66021	0.66781
0.53263	0.80319	0.27223	0.17667	0.10751	0.64898	0.29911	0.10627	0.66665	0.67447
0.54225	0.81141	0.28267	0.18510	0.10759	0.65483	0.28553	0.10677	0.67306	0.68109
0.55188	0.81959	0.29331	0.19378	0.10767	0.66066	0.27280	0.10734	0.67944	0.68767
0.56150	0.82773	0.30413	0.20269	0.10776	0.66646	0.26085	0.10798	0.68579	0.69421
0.57113	0.83583	0.31514	0.21184	0.10784	0.67223	0.24965	0.10868	0.69210	0.70072
0.58075	0.84390	0.32633	0.22125	0.10792	0.67799	0.23910	0.10945	0.69838	0.70719
0.59037	0.85195	0.33771	0.23090	0.10800	0.68371	0.22916	0.11029	0.70463	0.71363
0.60000	0.86000	0.34928	0.24080	0.10809	0.68942	0.21980	0.11118	0.71086	0.72005

THE MINIMUM VALUE OF CP IS 0.1050347 THE CORRESPONDING AREA RATIO IS 0.2220265

AND THE MASS FLOW RATE COEFFICIENT IS 0.1373917

THE AREA RATIO IS INCREASED BY 0.00000PERCENT TO THE DESIGN VALUE 0.2220265

CP AND FMASS ARE 0.1050347 AND 0.1373917 RESPECTIVELY

THE ADVANCE RATIO IS   0.67500

RT/RP	SIGMA
0.3464780	2.5431433
0.3785555	2.0341032
0.4064131	1.7335970
0.4324800	1.6708734
0.4570627	1.6352771
0.4803691	1.6554174
0.5026341	1.7050619
0.5239354	1.7768431
0.5444040	1.8642197
0.5641304	1.9629011
0.5831898	2.0679720

THE ADVANCE RATIO IS 0.67500

R/RB	CP-NEW	EFF-ROT	EFF-STAT	EFF-TOT	CL-STAT	CL-ROT	S/C-ROT	S/C-STAT	SGMA	RT/RB
0.12842	2.69296	0.99995	0.99999	0.99998	2.93394	0.33353	0.21881	2.00000	0.14932	0.12174
0.13805	1.31296	0.99995	0.99994	0.99988	3.04339	0.33035	0.20966	2.00000	0.16592	0.13325
0.14767	0.85591	0.99985	0.99983	0.99968	3.13569	0.32761	0.20242	2.00000	0.18346	0.14457
0.15730	0.62743	0.99967	0.99963	0.99932	3.21424	0.32524	0.19657	2.00000	0.20225	0.15574
0.16692	0.49508	0.99944	0.99931	0.99875	3.28164	0.32319	0.19176	2.00000	0.22219	0.16681
0.17654	0.40572	0.99905	0.99883	0.99788	3.33986	0.32139	0.18775	2.00000	0.24329	0.17778
0.18617	0.34459	0.99849	0.99814	0.99664	3.39042	0.31982	0.18437	2.00000	0.26555	0.18868
0.19579	0.29832	0.99773	0.99718	0.99491	3.43460	0.31843	0.18150	2.00000	0.28898	0.19951
0.20542	0.26375	0.99669	0.99589	0.99259	3.47336	0.31721	0.17903	2.00000	0.31358	0.21028
0.21504	0.23672	0.99533	0.99418	0.98954	3.50751	0.31613	0.17690	2.00000	0.33937	0.22101
0.22466	0.21505	0.99357	0.99199	0.98561	3.53772	0.31517	0.17505	2.00000	0.36634	0.23171
0.23429	0.19758	0.99134	0.98920	0.98064	3.56457	0.31431	0.17343	2.00000	0.39450	0.24236
0.24391	0.18332	0.98855	0.98572	0.97444	3.58854	0.31354	0.17200	2.00000	0.42384	0.25299
0.25354	0.17141	0.98511	0.98359	0.96894	3.12174	0.31285	0.17073	1.72943	0.45436	0.26359
0.26316	0.16115	0.98092	0.98330	0.96454	2.32009	0.31222	0.16961	1.27349	0.48605	0.27416
0.27278	0.15268	0.97558	0.98239	0.95869	1.71882	0.31166	0.16860	0.94261	0.51891	0.28472
0.28241	0.14579	0.96985	0.98026	0.95071	1.26087	0.31114	0.16769	0.68847	0.55294	0.29526
0.29203	0.14043	0.96275	0.97581	0.93946	0.90719	0.31067	0.16687	0.49340	0.58814	0.30578
0.30165	0.13583	0.95203	0.97544	0.92869	0.91952	0.31024	0.18305	0.50565	0.62452	0.31628
0.31128	0.13138	0.93859	0.97855	0.91845	1.25865	0.30985	0.22064	0.71679	0.66208	0.32677
0.32090	0.12883	0.92565	0.97921	0.90641	1.60398	0.30949	0.26371	0.95236	0.70082	0.33725
0.33053	0.12631	0.91372	0.97885	0.89439	1.93960	0.30916	0.31273	1.21049	0.74075	0.34772
0.34015	0.12416	0.90305	0.97804	0.88322	2.25119	0.30886	0.36317	1.48868	0.78186	0.35818
0.34977	0.12228	0.89372	0.97712	0.87327	2.52744	0.30858	0.43048	1.78435	0.82414	0.36863
0.35940	0.12050	0.88574	0.97711	0.86546	2.63583	0.30832	0.50914	2.00000	0.86760	0.37907
0.36902	0.11867	0.87903	0.97894	0.86057	2.43882	0.30808	0.57759	2.00000	0.91223	0.38950
0.37865	0.11702	0.87367	0.98057	0.85669	2.24657	0.30786	0.66327	2.00000	0.95803	0.39993
0.38827	0.11553	0.86945	0.98202	0.85392	2.06304	0.30765	0.75764	2.00000	1.00498	0.41035
0.39789	0.11415	0.86637	0.98330	0.85190	1.89942	0.30745	0.86111	2.00000	1.05309	0.42076
0.40752	0.11276	0.86435	0.98442	0.85089	1.73020	0.30726	0.97413	2.00000	1.10235	0.43116
0.41714	0.11193	0.86336	0.98540	0.85076	1.58295	0.30709	1.09712	2.00000	1.15277	0.44157
0.42677	0.11081	0.86334	0.98624	0.85147	1.44859	0.30693	1.23047	2.00000	1.20434	0.45196
0.43639	0.10985	0.86423	0.98695	0.85300	1.32663	0.30677	1.37460	2.00000	1.25707	0.46235
0.44601	0.10898	0.86613	0.98754	0.85533	1.21632	0.30663	1.52985	2.00000	1.31094	0.47274
0.45564	0.10815	0.86887	0.98802	0.85846	1.11679	0.30649	1.69660	2.00000	1.36594	0.48312
0.46526	0.10824	0.86560	0.98839	0.85555	1.02709	0.29407	1.80000	2.00000	1.42209	0.49350
0.47489	0.10976	0.85191	0.98862	0.84227	0.94629	0.26681	1.80000	2.00000	1.47937	0.50388
0.48451	0.11165	0.83698	0.98888	0.82767	0.87343	0.24232	1.80000	2.00000	1.53778	0.51425
0.49413	0.11374	0.82076	0.98901	0.81174	0.80782	0.22163	1.80000	2.00000	1.59732	0.52462
0.50376	0.11659	0.80323	0.98909	0.79445	0.74853	0.20285	1.80000	2.00000	1.65798	0.53499
0.51338	0.11969	0.78435	0.98908	0.77578	0.69492	0.18615	1.80000	2.00000	1.71978	0.54535
0.52301	0.12326	0.76410	0.98902	0.75571	0.64636	0.17125	1.80000	2.00000	1.78270	0.55571
0.53263	0.12737	0.74243	0.98892	0.73420	0.60231	0.15791	1.80000	2.00000	1.84675	0.56607
0.54225	0.13210	0.71931	0.98876	0.71123	0.56227	0.14525	1.80000	2.00000	1.91193	0.57643
0.55188	0.13754	0.69471	0.98857	0.68677	0.52581	0.13518	1.80000	2.00000	1.97824	0.58678
0.56150	0.14379	0.66860	0.98833	0.66080	0.49255	0.12546	1.80000	2.00000	2.04568	0.59713
0.57113	0.15102	0.64095	0.98806	0.63330	0.46215	0.11658	1.80000	2.00000	2.11424	0.60748
0.58075	0.15941	0.61171	0.98776	0.60422	0.43433	0.10871	1.80000	2.00000	2.18393	0.61783
0.59037	0.16921	0.58087	0.98742	0.57357	0.40881	0.10147	1.80000	2.00000	2.25475	0.62817
0.60000	0.18076	0.54839	0.98706	0.54130	0.38536	0.09488	1.80000	2.00000	2.32670	0.63852

THE ADVANCE RATIO IS 0.34400

RT/RB	SIGMA
0.3494720	2.2517461
0.3785555	1.6984997
0.4054131	1.3967762
0.4324800	1.2323453
0.4570527	1.1470326
0.4803691	1.1149607
0.5026341	1.1133928
0.5239354	1.1339526
0.5444040	1.1701263
0.5641304	1.2175961
0.5831898	1.2734556

THE ADVANCE RATIO IS 0.84490

R/RF	CP-NEW	EFF-ROT	EFF-STAT	EFF-TOT	CL-STAT	CL-ROT	S/C-ROT	S/C-STAT	SGMA	RT/R3
0.12842	2.69294	0.99999	0.99999	0.99998	2.61345	0.34241	0.24975	2.00000	0.12121	0.12174
0.13805	1.31292	0.99996	0.99996	0.99992	2.73607	0.33909	0.23710	2.00000	0.13214	0.13325
0.14767	0.85533	0.99989	0.99983	0.99977	2.84221	0.33614	0.22699	2.00000	0.14381	0.14457
0.15730	0.62731	0.99978	0.99974	0.99951	2.93466	0.33351	0.21875	2.00000	0.15623	0.15574
0.16692	0.47459	0.99959	0.99952	0.99911	3.01563	0.33116	0.21193	2.00000	0.16940	0.16681
0.17654	0.40647	0.99932	0.99918	0.99850	3.08686	0.32907	0.20620	2.00000	0.18333	0.17778
0.18617	0.34424	0.99893	0.99871	0.99764	3.14977	0.32719	0.20135	2.00000	0.19802	0.18868
0.19579	0.29836	0.99840	0.99805	0.99645	3.20553	0.32551	0.19720	2.00000	0.21347	0.19951
0.20542	0.26335	0.99769	0.99710	0.99489	3.25510	0.32400	0.19363	2.00000	0.22970	0.21028
0.21504	0.23594	0.99677	0.99604	0.99282	3.29929	0.32264	0.19053	2.00000	0.24671	0.22101
0.22466	0.21406	0.99560	0.99458	0.99020	3.33880	0.32142	0.18782	2.00000	0.26450	0.23171
0.23429	0.19633	0.99412	0.99273	0.98689	3.37425	0.32032	0.18544	2.00000	0.28309	0.24236
0.24391	0.18182	0.99229	0.99045	0.98281	3.40617	0.31933	0.18334	2.00000	0.30243	0.25299
0.25354	0.16985	0.99005	0.98765	0.97782	3.43502	0.31842	0.18147	2.00000	0.32256	0.26359
0.26316	0.15994	0.98734	0.98427	0.97180	3.46120	0.31760	0.17980	2.00000	0.34346	0.27416
0.27278	0.15122	0.98410	0.98360	0.96795	2.77559	0.31684	0.17930	1.59287	0.36513	0.28472
0.28241	0.14382	0.98026	0.98320	0.96379	2.13256	0.31615	0.17695	1.21626	0.38757	0.29526
0.29203	0.13765	0.97575	0.98221	0.95840	1.63339	0.31552	0.17572	0.92659	0.41078	0.30578
0.30165	0.13251	0.97050	0.98019	0.95127	1.24234	0.31494	0.17461	0.70092	0.43476	0.31628
0.31128	0.12854	0.96443	0.97634	0.94161	0.93139	0.31440	0.17361	0.52302	0.45952	0.32677
0.32090	0.12560	0.95709	0.97136	0.92768	0.74471	0.31391	0.17671	0.41836	0.48506	0.33725
0.33053	0.12225	0.94686	0.97593	0.92406	1.00623	0.31346	0.20925	0.58606	0.51139	0.34772
0.34015	0.11975	0.93689	0.97751	0.91581	1.26333	0.31304	0.24601	0.76855	0.53849	0.35818
0.34977	0.11774	0.92753	0.97780	0.90694	1.50739	0.31265	0.28728	0.96391	0.56637	0.36863
0.35940	0.11609	0.91893	0.97754	0.89833	1.72820	0.31229	0.33338	1.17002	0.59502	0.37907
0.36902	0.11467	0.91133	0.97707	0.89043	1.92007	0.31195	0.38458	1.38491	0.62444	0.38950
0.37865	0.11343	0.90451	0.97660	0.88344	2.07995	0.31164	0.44118	1.60705	0.65462	0.39993
0.38827	0.11242	0.89881	0.97622	0.87744	2.20774	0.31134	0.50345	1.83550	0.68556	0.41035
0.39789	0.11143	0.89391	0.97656	0.87295	2.22770	0.31107	0.57170	2.00000	0.71725	0.42076
0.40752	0.11042	0.88985	0.97818	0.87043	2.05766	0.31080	0.64617	2.00000	0.74970	0.43116
0.41714	0.10955	0.88659	0.97963	0.86853	1.89734	0.31056	0.72717	2.00000	0.78290	0.44157
0.42677	0.10879	0.88410	0.98091	0.86722	1.74784	0.31033	0.81493	2.00000	0.81685	0.45196
0.43639	0.10815	0.88232	0.98203	0.86647	1.60965	0.31011	0.90973	2.00000	0.85155	0.46235
0.44601	0.10761	0.88124	0.98301	0.86627	1.48272	0.30990	1.01178	2.00000	0.88699	0.47274
0.45564	0.10715	0.88081	0.98385	0.86658	1.36671	0.30970	1.12133	2.00000	0.92318	0.48312
0.46526	0.10676	0.88101	0.98456	0.86740	1.26104	0.30951	1.23859	2.00000	0.96009	0.49350
0.47489	0.10644	0.88180	0.98515	0.86871	1.16499	0.30933	1.36374	2.00000	0.99774	0.50388
0.48451	0.10618	0.88319	0.98564	0.87050	1.07779	0.30915	1.49703	2.00000	1.03612	0.51425
0.49413	0.10597	0.88514	0.98602	0.87277	0.99866	0.30899	1.63863	2.00000	1.07522	0.52462
0.50376	0.10580	0.88766	0.98631	0.87551	0.92684	0.30883	1.78876	2.00000	1.11505	0.53499
0.51338	0.10709	0.87687	0.98652	0.86703	0.85161	0.28528	1.80000	2.00000	1.15561	0.54535
0.52301	0.10871	0.86843	0.98666	0.85685	0.80231	0.26254	1.80000	2.00000	1.19689	0.55571
0.53263	0.11056	0.85720	0.98673	0.84582	0.74834	0.24218	1.80000	2.00000	1.23890	0.56607
0.54225	0.11266	0.84517	0.98673	0.83396	0.69715	0.22390	1.80000	2.00000	1.28163	0.57643
0.55188	0.11502	0.83232	0.98668	0.82123	0.65428	0.20744	1.80000	2.00000	1.32510	0.58678
0.56150	0.11765	0.81864	0.98659	0.80765	0.61325	0.19259	1.80000	2.00000	1.36928	0.59713
0.57113	0.12058	0.80411	0.98643	0.79320	0.57570	0.17915	1.80000	2.00000	1.41420	0.60748
0.58075	0.12383	0.78873	0.98623	0.77787	0.54128	0.16697	1.80000	2.00000	1.45984	0.61783
0.59037	0.12743	0.77247	0.98600	0.76165	0.50967	0.15589	1.80000	2.00000	1.50620	0.62817
0.60000	0.13141	0.75532	0.98572	0.74454	0.48059	0.14580	1.80000	2.00000	1.55330	0.63852

THE ADVANCE RATIO IS 1.12500

RT/RH	SIGMA
0.3484730	2.0330802
0.3745555	1.4330980
0.4064131	1.0966387
0.4324800	0.8929732
0.4570627	0.7694249
0.4803491	0.6756156
0.5026341	0.6543132
0.5239354	0.6351475
0.5444040	0.6315765
0.5641304	0.6393092
0.5331898	0.6554335

May 3, 1979
WSG:JEF:mmj

THE ADVANCE RATIO IS 1.12500

R/RB	CP-NEW	EFF-ROT	EFF-STAT	EFF-TOT	CL-STAT	CL-ROT	S/C-ROT	S/C-STAT	SGMA	RT/RB
0.12842	2.69293	0.99999	0.99999	0.99999	2.17398	0.35337	0.30625	2.00000	0.09939	0.12174
0.13805	1.31289	0.99997	0.99997	0.99994	2.30149	0.35035	0.28773	2.00000	0.10600	0.13325
0.14767	0.85577	0.99992	0.99992	0.99985	2.41545	0.34753	0.27277	2.00000	0.11305	0.14457
0.15730	0.62921	0.99984	0.99933	0.99967	2.51771	0.34492	0.26045	2.00000	0.12053	0.15574
0.16692	0.49476	0.99972	0.99969	0.99940	2.60973	0.34251	0.25016	2.00000	0.12845	0.16681
0.17654	0.40525	0.99953	0.99947	0.99900	2.69274	0.34028	0.24145	2.00000	0.13681	0.17778
0.18617	0.34397	0.99927	0.99917	0.99844	2.76775	0.33822	0.23401	2.00000	0.14562	0.18868
0.19579	0.29800	0.99892	0.99876	0.99767	2.83565	0.33633	0.22759	2.00000	0.15489	0.19951
0.20542	0.26262	0.99845	0.99820	0.99665	2.89717	0.33459	0.22203	2.00000	0.16462	0.21023
0.21504	0.23534	0.99786	0.99749	0.99535	2.95299	0.33298	0.21717	2.00000	0.17481	0.22101
0.22466	0.21331	0.99710	0.99657	0.99368	3.00371	0.33151	0.21291	2.00000	0.18548	0.23171
0.23429	0.19540	0.99616	0.99543	0.99161	3.04990	0.33016	0.20914	2.00000	0.19652	0.24236
0.24391	0.18067	0.99501	0.99402	0.98906	3.09205	0.32891	0.20560	2.00000	0.20823	0.25299
0.25354	0.16845	0.99351	0.99230	0.98596	3.13062	0.32776	0.20281	2.00000	0.22030	0.26359
0.26316	0.15824	0.99193	0.99024	0.98226	3.16502	0.32670	0.20013	2.00000	0.23283	0.27416
0.27278	0.14968	0.98995	0.98779	0.97786	3.19958	0.32572	0.19771	2.00000	0.24581	0.28472
0.28241	0.14250	0.98761	0.98491	0.97271	3.22859	0.32481	0.19553	2.00000	0.25926	0.29526
0.29203	0.13621	0.98490	0.98339	0.96854	2.96205	0.32396	0.19354	1.75785	0.27316	0.30578
0.30165	0.13070	0.98175	0.98308	0.96514	2.23514	0.32318	0.19174	1.39253	0.28752	0.31628
0.31128	0.12585	0.97814	0.98240	0.96092	1.82435	0.32245	0.19009	1.10382	0.30235	0.32677
0.32090	0.12219	0.97402	0.98111	0.95562	1.45264	0.32178	0.18859	0.87314	0.31765	0.33725
0.33053	0.11905	0.96934	0.97886	0.94886	1.15008	0.32115	0.18722	0.68709	0.33342	0.34772
0.34015	0.11666	0.96407	0.97508	0.94005	0.90177	0.32056	0.18595	0.53573	0.34966	0.35818
0.34977	0.11504	0.95316	0.96879	0.92326	0.69643	0.32002	0.18479	0.41160	0.36636	0.36863
0.35940	0.11334	0.95132	0.96974	0.92253	0.75613	0.31951	0.20310	0.45823	0.38352	0.37907
0.36902	0.11116	0.94434	0.97286	0.91871	0.93027	0.31903	0.23366	0.58990	0.40114	0.38950
0.37865	0.10974	0.93759	0.97426	0.91356	1.08938	0.31858	0.26780	0.72694	0.41921	0.39993
0.38827	0.10863	0.93150	0.97485	0.90807	1.22952	0.31815	0.30509	0.86795	0.43772	0.41035
0.39789	0.10775	0.92584	0.97505	0.90275	1.34847	0.31775	0.34563	1.01175	0.45668	0.42076
0.40752	0.10705	0.92075	0.97514	0.89785	1.44571	0.31737	0.39037	1.15749	0.47607	0.43116
0.41714	0.10649	0.91622	0.97519	0.89349	1.52216	0.31702	0.43868	1.30470	0.49592	0.44157
0.42677	0.10604	0.91225	0.97530	0.88972	1.57974	0.31668	0.49096	1.45322	0.51619	0.45196
0.43639	0.10570	0.90883	0.97547	0.88653	1.62095	0.31635	0.54736	1.60322	0.53691	0.46235
0.44601	0.10546	0.90592	0.97572	0.88392	1.64862	0.31604	0.60802	1.75509	0.55806	0.47274
0.45564	0.10529	0.90350	0.97604	0.88185	1.66536	0.31575	0.67306	1.90741	0.57963	0.48312
0.46526	0.10516	0.90155	0.97679	0.88062	1.61953	0.31547	0.74261	2.00000	0.60163	0.49350
0.47489	0.10506	0.90004	0.97794	0.88018	1.50410	0.31520	0.81678	2.00000	0.62404	0.50388
0.48451	0.10503	0.89894	0.97895	0.88002	1.39775	0.31494	0.89568	2.00000	0.64688	0.51425
0.49413	0.10502	0.89824	0.97982	0.88011	1.30005	0.31469	0.97942	2.00000	0.67013	0.52462
0.50376	0.10523	0.89791	0.98056	0.88046	1.21044	0.31445	1.06313	2.00000	0.69379	0.53499
0.51338	0.10538	0.89795	0.98119	0.88106	1.12832	0.31422	1.16190	2.00000	0.71786	0.54535
0.52301	0.10562	0.89834	0.98170	0.88191	1.05311	0.31399	1.26083	2.00000	0.74236	0.55571
0.53263	0.10591	0.89907	0.98212	0.88299	0.98421	0.31378	1.36504	2.00000	0.76726	0.56607
0.54225	0.10624	0.90012	0.98245	0.88432	0.92107	0.31357	1.47461	2.00000	0.79258	0.57643
0.55188	0.10652	0.90149	0.98269	0.88583	0.86319	0.31337	1.58962	2.00000	0.81832	0.58678
0.56150	0.10704	0.90317	0.98285	0.88759	0.81007	0.31318	1.71017	2.00000	0.84446	0.59713
0.57113	0.10778	0.90274	0.98295	0.88734	0.76128	0.30690	1.80000	2.00000	0.87103	0.60748
0.58075	0.10936	0.89600	0.98293	0.88075	0.71641	0.28608	1.80000	2.00000	0.89801	0.61783
0.59037	0.11169	0.88885	0.98295	0.87369	0.67511	0.26724	1.80000	2.00000	0.92540	0.62817
0.60000	0.11296	0.88126	0.98287	0.86616	0.63704	0.25007	1.80000	2.00000	0.95321	0.63852

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// READ DEVICE-SYSIN
// PRINT DEVICE-PRTR
*PROCESS MAP,LINK(R,LIB(JEFLIB)),SIZE(24)
          PROGRAM PSPPOP
          REAL LORB,MSFLO
          DIMENSION AA(60),A(60),AOAB(60),A2OAB(60),B(60),C(60),CP(60)
          DIMENSION CPP(60),CT(60),DLTAV(60),EL(60),FFF(60),FF(60),F(60)
          DIMENSION V(60),VBAR(60),VMOM(60),VENG(60),VVMOM(60),VVENG(60)
          DIMENSION FMASS(60),RR(60),R(60),RT(60),SC(60),SIGMA(60),VV(60)
          DIMENSION CPPP(60),RTRB(60),CLS(60),CLR(60),SOCR(60),SOCS(60)
          DIMENSION EROT(60),ESTAT(60),ETOT(60),SGMA(60)
          EQUIVALENCE (A(1),VVMOM(1)),(B(1),VVENG(1))
C
C         THE PRELIMINARY PUMPJET DESIGN COMPUTER PROGRAM SELECTS AN
C         OPTIMUM FLOW AREA FROM THE REFERENCE VELOCITY PROFILE BASED ON
C         A MINIMUM VALUE OF PROPULSIVE COEFFICIENT.  FROM THESE DATA THE
C         PROGRAM ALSO PREDICTS THE CAVITATION PERFORMANCE AS A FUNCTION
C         OF ADVANCE RATIO AND ROTOR TIP DIAMETER.
C         ADDITIONALLY, THE PROGRAM COMPUTES THE SPACE TO CHORD RATIO,
C         LIFT COEFFICIENT, STAGE EFFICIENCY, AND TOTAL PUMPJET
C         EFFICIENCY AS A FUNCTION OF INGESTED MASS FLOW AND ADVANCE RATIO.
C
          READ(4,100)N
          DO 1 I=1,N
        1 READ(4,101)R(I),V(I)
          READ(4,101)CDBB,CDS,V1OV2,ETAH
          READ(4,101)PHI,LORB,RH1,RH2
          CALL SPFIT(N,R,V,SC,EL,A,B,C)
C
C         N IS THE NUMBER OF DATA POINTS DEFINING THE THE REFERENCE VELOCITY
C         PROFILE
C         R(I) AND V(I) ARE THE DATA POINTS DEFINING THE REFERENCE VELOCITY
C         PROFILE
C         CDBB IS THE BARE BODY DRAG COEFFICIENT
C         CDS IS THE SKIN FRICTION DRAG COEFFICIENT
C         V1OV2 IS A VELOCITY RATIO WHICH REPRESENTS THE ACCELERATION OF THE
C         FLUID FROM THE REFERENCE STATION TO THE ROTOR DISK PLANE
C         ETAH IS THE HYDRAULIC EFFICIENCY
C         PHI IS THE LOCAL BODY ANGLE AT THE REFERENCE STATION WITH RESPECT
C         TO THE VEHICLE CENTERLINE
C         LORB IS THE NONDIMENSIONAL SHROUD LENGTH
C         RH1 IS THE NONDIMENSIONAL BODY RADIUS AT THE REFERENCE STATION
C         RH2 IS THE NONDIMENSIONAL BODY RADIUS AT THE ROTOR HUB
C
          DLTAR=(R(N)-R(1))/50.0
          RR(1)=R(1)
          DO 2 I=2,51
        2 RR(I)=RR(I-1)+DLTAR
          DO 3 I=1,51
          CALL SPGET(N,R,V,SC,EL,RR(I),VV(I),YP,DP)
```


May 3, 1979
WSG:JEF:mmj

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  22          CT(I)=1.00*CDBB+4.0*CDS*LORB*SQRT(V1OV2*((RR(I))**2-RH1**2)+
             -RH2**2)
        C
        C     CT(I) IS THE REQUIRED THRUST COEFFICIENT
        C
  23        3 F(I)=2.0*RR(I)/COS(PHI)
  24          AOAB(1)=0.0
  25          DO 4 I=2,51
  26        4 AOAB(I)=AOAB(I-1)+0.5*(F(I)+F(I-1))*(RR(I)-RR(I-1))
        C
        C     AOAB(I) IS THE FLOW AREA AT THE REFERENCE STATION AS A FUNCTION OF
        C     R/RB
        C
  27          DO 5 I=1,51
  28          F(I)=2.0*(VV(I)*RR(I)/COS(PHI))
  29          FF(I)=VV(I)*F(I)
  30        5 FFF(I)=VV(I)*FF(I)
  31          FMASS(1)=0.0
  32          VVMOM(1)=0.0
  33          VVENG(1)=0.0
  34          DO 6 I=2,51
  35          FMASS(I)=FMASS(I-1)+0.5*(F(I)+F(I-1))*(RR(I)-RR(I-1))
  36          VVMOM(I)=VVMOM(I-1)+0.5*(FF(I)+FF(I-1))*(RR(I)-RR(I-1))
  37          VVENG(I)=VVENG(I-1)+0.5*(FFF(I)+FFF(I-1))*(RR(I)-RR(I-1))
  38          VBAR(I)=FMASS(I)/AOAB(I)
  39          VMOM(I)=VVMOM(I)/FMASS(I)
  40          VENG(I)=SQRT(VVENG(I)/FMASS(I))
  41        6 DLTAV(I)=0.5*(CT(I)/(COS(PHI)*AOAB(I)*VMOM(I)))
        C
        C     FMASS(I) IS THE MASS FLOW RATE COEFFICIENT
        C     VBAR(I) IS AN AVERAGE VELOCITY RATIO BASED ON MASS FLOW RATE
        C     VMOM(I) IS AN AVERAGE VELOCITY RATIO BASED ON MOMENTUM
        C     VENG(I) IS AN AVERAGE VELOCITY RATIO BASED ON ENERGY
        C     DLTAV(I) IS THE NONDIMENSIONAL VELOCITY CHANGE BASED ON MOMENTUM
        C
  42          READ(4,101)XXK
  43          WRITE(3,104)XXK
  44          WRITE(3,105)
        C
        C     XXK IS THE LOSS COEFFICIENT
        C
  45          WRITE(3,102)RR(1),VV(1),AOAB(1),FMASS(1),CT(1)
  46          DO 7 I=2,51
  47          CP(I)=(2.0*DLTAV(I)*VENG(I)+DLTAV(I)**2+XXK*VENG(I)**2)
             -*AOAB(I)*VBAR(I)/ETAH
  48        7 WRITE(3,102)RR(I),VV(I),AOAB(I),FMASS(I),CT(I),VBAR(I),DLTAV(I),
             -CP(I),VMOM(I),VENG(I)
        C
        C     THE FOLLOWING STATEMENTS (THROUGH 12) LOCATE THE POINT OF
        C     MINIMUM PROPULSIVE COEFFICIENT
        C
```

```
      DO 9 I=1,48
      CPP(I)=CP(I+3)
    9 AA(I)=AOAB(I+3)
      CALL SPFIT(48,AA,CPP,SC,EL,A,B,C)
      AINC=AOAB(51)/1000.0
      AAA=AOAB(4)
      CALL SPGET(48,AA,CPP,SC,EL,AAA,Y,YD,YDP)
      AQ=AAA
      YQ=Y
      DO 11 I=1,1000
      AAA=AAA+AINC
      CALL SPGET(48,AA,CPP,SC,EL,AAA,Y,YD,YDP)
      IF(Y-YQ)10,12,12
   10 AQ=AAA
      YQ=Y
   11 CONTINUE
   12 AMIN1=0.5*(AQ+AAA)
      READ(4,101)PRCNT
      AMIN2=(1.0+PRCNT)*AMIN1
C
C     AMIN1 IS THE FLOW AREA AT THE REFERENCE STATION CORRESPONDING TO
C     THE POINT OF MINIMUM PROPULSIVE COEFFICIENT
C     PRCNT IS THE AMOUNT BY WHICH THE DESIGNER INCREASES AMIN1 TO AMIN2
C     AMIN2 IS THE DESIGN VALUE OF THE FLOW AREA AT THE REFERENCE
C     STATION
C
      CALL SPGET(48,AA,CPP,SC,EL,AMIN1,Y1,YP,YDP)
      CALL SPGET(48,AA,CPP,SC,EL,AMIN2,Y2,YP,YDP)
      CALL SPFIT(51,AOAB,FMASS,SC,EL,A,B,C)
      CALL SPGET(51,AOAB,FMASS,SC,EL,AMIN1,Y3,YP,YDP)
      CALL SPGET(51,AOAB,FMASS,SC,EL,AMIN2,Y4,YP,YDP)
      WRITE(3,111)Y1,AMIN1,Y3
      P=100.0*PRCNT
      WRITE(3,112)P,AMIN2,Y2,Y4
      VENG(1)=0.0
      CALL SPFIT(51,AOAB,VENG,SC,EL,A,B,C)
      CALL SPGET(51,AOAB,VENG,SC,EL,AMIN2,Y5,YP,YDP)
      MSFLO=AMIN2*Y5
C
C     MSFLO IS A MASS FLOW RATE COEFFICIENT BASED ON VENG(I)
C     RT(I) IS THE NONDIMENSIONAL ROTOR TIP RADIUS
C     SIGMA(I) IS THE CAVITATION INDEX
C
      AINC2=AMIN2/10.0
      A2OAB(1)=AMIN2/2.0
      READ(4,101)CB,PHI2
C
C     CB IS AN ASSUMED VALUE OF THE MINIMUM PRESSURE COEFFICIENT OF THE
C     BLADE TIP SECTION
C     PH2 IS THE LOCAL FLOW ANGLE AT THE ROTOR HUB IN RADIANS
C
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   83            RT(1)=SQRT(A2OAB(1)*COS(PHI2)+RH2**2)
   84            DO 13 I=2,11
   85            A2OAB(I)=A2OAB(I-1)+AINC2
   86         13 RT(I)=SQRT(A2OAB(I)*COS(PHI2)+RH2**2)
   87            READ(4,100)NN
   88            DO 29 J=1,NN
   89            READ(4,101)ADRAT
   90            IF(J.NE.1) GO TO 15
   91            WRITE(3,106)ADRAT
   92            GO TO 17
   93         15 WRITE(3,114)ADRAT
   94         17 WRITE(3,107)
   95            DO 19 I=1,11
   96            SIGMA(I)=CB*(MSFLO**2/(A2OAB(I)**2)+((3.1416/ADRAT)**2)*RT(I)**2+
              -0.990+0.245*((ADRAT/3.1416)**2)/RT(I)**2)+MSFLO**2*(1.0/A2OAB(I)**
              -2-0.95/(AMIN2**2))+0.245*(ADRAT/3.1416)**2/RT(I)**2
   97         19 WRITE(3,108)RT(I),SIGMA(I)
           C
   98            WRITE(3,114)ADRAT
   99            WRITE(3,115)
  100            DO 27 I=2,51
           C
           C     STATOR APPLICATION
           C
  101            HBAR=2.*DLTAV(I)*VBAR(I)+DLTAV(I)**2+XXK*VBAR(I)**2
  102            RTRB(I)=SQRT(ADAB(I)*V1OV2*COS(PHI2)+RH2**2)
  103            UBARS=0.9*3.1416*RTRB(I)/ADRAT
  104            VTHVS=HBAR/(2.*UBARS)
  105            IF(VTHVS.LE.UBARS) GO TO 21
  106            VTHVS=UBARS
  107         21 CONTINUE
  108            WOVS=1.
  109            CLSA=1.4
  110            SOCS(I)=0.5*CLSA/VTHVS
  111            IF(SOCS(I).LT.2.) GO TO 23
  112            SOCS(I)=2.
  113         23 CONTINUE
  114            CLS(I)=2.*SOCS(I)*VTHVS/WOVS
  115            CDPS=0.012-.004*SOCS(I)
  116            CDSS=0.018*CLS(I)**2
  117            CDS=CDPS+CDSS
  118            ALP1S=0.
  119            CA1S=1.
  120            ALP2S=ATAN(VTHVS/VBAR(I))
  121            ALPMS=ATAN(0.5*(SIN(ALP2S)/COS(ALP2S)))
  122            CAMS=COS(ALPMS)
  123            PLOSS=CDS*CA1S**2/(SOCS(I)*CAMS**3)
  124            ESTAT(I)=1.-PLOSS*WOVS**2/HBAR
           C
           C     ROTOR APPLICATION
           C
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          VTHVR=VTHVS
          UBARR=0.9*3.1416*RTRB(I)/ADRAT+VTHVR
          W1OV=SQRT(UBARR**2+VBAR(I)**2)
          SGMA(I)=CB*W1OV**2+VTHVR**2+XXK*VBAR(I)**2
          SOCR(I)=(SGMA(I)-VTHVR**2)/(2.*VTHVR*W1OV)
          IF(SOCR(I).LT.1.8) GO TO 25
          SOCR(I)=1.8
       25 CONTINUE
          CLR(I)=2.*VTHVR*SOCR(I)/W1OV
          CDPR=0.020-0.004*SOCR(I)
          CDSR=0.018*CLR(I)**2
          CDR=CDPR+CDSR
          ALP1R=ATAN(UBARR/VBAR(I))
          CA1R=COS(ALP1R)
          ALP2R=ATAN(UBARS/(1.25*VBAR(I)))
          TN1=SIN(ALP1R)/COS(ALP1R)
          TN2=SIN(ALP2R)/COS(ALP2R)
          ALPMR=ATAN((TN1+TN2)/2.)
          CAMR=COS(ALPMR)
          PLOSR=CDR*CA1R**2/(SOCR(I)*CAMR**3)
          EROT(I)=1.-PLOSR*W1OV**2/HBAR
          ETOT(I)=EROT(I)*ESTAT(I)
          CPPP(I)=CP(I)*ETAH/ETOT(I)
       27 WRITE(3,110)RR(I),CPPP(I),EROT(I),ESTAT(I),ETOT(I),CLS(I),CLR(I),
         -SOCR(I),SOCS(I),SGMA(I),RTRB(I)
       29 CONTINUE
C
C         HBAR IS THE NONDIMENSIONAL EXPRESSION FOR THE ENERGY
C         PLACED IN THE FLUID
C         UBARR IS THE PERIPHERAL RELATIVE VELOCITY COMPONENT
C         AT THE ROTOR INLET
C         UBARS IS THE ROTOR PERIPHERAL VELOCITY RATIO AT 0.9 RT/RB
C         RTRB(I) IS THE NONDIMENSIONAL ROTOR TIP RADIUS
C         VTHVR IS AN AVERAGE PERIPHERAL ABSOLUTE VELOCITY RATIO
C         AT THE ROTOR LEADING EDGE
C         W1OV IS AN AVERAGE RELATIVE VELOCITY RATIO AT THE
C         ROTOR LEADING EDGE
C         SOCR(I) IS THE BLADE SPACING TO CHORD RATIO FOR THE ROTOR
C         CLR(I) IS THE ROTOR LIFT COEFFICIENT
C         CDPR IS THE ROTOR PROFILE DRAG COEFFICIENT
C         CDSR IS THE ROTOR SECONDARY FLOW DRAG COEFFICIENT
C         CDR IS THE ROTOR DRAG COEFFICIENT
C         EROT(I) IS THE ROTOR HYDRAULIC EFFICIENCY
C         PLOSR IS THE PRESSURE LOSS THROUGH THE ROTOR
C         VTHVS IS AN AVERAGE PERIPHERAL ABSOLUTE VELOCITY RATIO
C         AT THE STATOR INLET
C         WOVS IS AN AVERAGE RELATIVE VELOCITY RATIO AT THE STATOR INLET
C         SOCS(I) IS THE BLADE SPACING TO CHORD RATIO FOR THE STATOR
C         CLS(I) IS THE STATOR LIFT COEFFICIENT
C         CDPS IS THE STATOR PROFILE DRAG COEFFICIENT
C         CDSS IS THE STATOR SECONDARY FLOW DRAG COEFFICIENT
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           C      CDS IS THE STATOR DRAG COEFFICIENT
           C      PLOSS IS THE PRESSURE LOSS THROUGH THE STATOR
           C      ESTAT(I) IS THE STATOR HYDRAULIC EFFICIENCY
           C      ETOT(I) IS THE TOTAL PUMPJET HYDRAULIC EFFICIENCY
           C      CPPP(I) IS THE PROPULSIVE COEFFICIENT AS A FUNCTION
           C      OF CALCULATED TOTAL EFF. VS ASSUMED TOTAL EFF.
           C      SGMA(I) IS THE CAVITATION INDEX FOR A GIVEN MASS FLOW
           C
   150        100 FORMAT(I5)
   151        101 FORMAT(5F10.5)
   152        102 FORMAT(' ',10(F8.5,4X))
   153        104 FORMAT('1','THE LOSS COEFFICIENT, K, IS',F10.5)
   154        105 FORMAT(' ',1X,'R/RB',8X,'V/VREF',6X,'A/AB',8X,'FMASS',7X,'CT'
                 -,9X,'VBAR/VREF',3X,'DELV/VREF',4X,'CP',9X,'VMOM/VREF',2X,
                 -'VENG/VREF')
   155        106 FORMAT('0','THE ADVANCE RATIO IS',F10.5)
   156        107 FORMAT(' ',' RT/RB',7X,'SIGMA')
   157        108 FORMAT(' ',2(F10.7,3X))
   158        110 FORMAT(' ',10(F8.5,3X),F8.5)
   159        111 FORMAT('1','THE MINIMUM VALUE OF CP IS ',F10.7,' THE CORRESPONDING
                 - AREA RATIO IS',F10.7,//' AND THE MASS FLOW RATE COEFFICIENT IS',
                 -F10.7)
   160        112 FORMAT('0','THE AREA RATIO IS INCREASED BY',F10.5,'PERCENT TO THE
                 -DESIGN VALUE ',F10.7,//' CP AND FMASS ARE',F10.7,' AND ',F10.7,
                 -' RESPECTIVELY')
   161        114 FORMAT('1','THE ADVANCE RATIO IS',F10.5)
   162        115 FORMAT(' ',1X,'R/RB',7X,'CP-NEW',5X,'EFF-ROT',3X,'EFF-STAT',4X,'EF
                 -F-TOT',4X,'CL-STAT',4X,'CL-ROT',5X,'S/C-ROT',3X,'S/C-STAT',4X,'SGM
                 -A',7X,'RT/RB')
           C
   163            CALL EXIT
   164            END

        VARIABLE ALLOCATION MAP
     NAME    AT HEX1 DEC1  HEX2 DEC2      NAME    AT HEX1 DEC1  HEX2 DEC2
     LORB    R  01AD 00429                MSFLO   R  01B1 00433
     AA      R  01B5 00437 02A4 00676     AOAB    R  02A5 00677 0394 00916
     A2OAB   R  0395 00917 0484 01156     C       R  0485 01157 0574 01396
     CP      R  0575 01397 0664 01636     CPP     R  0665 01637 0754 01876
     CT      R  0755 01877 0844 02116     DLTAV   R  0845 02117 0934 02356
     EL      R  0935 02357 0A24 02596     FFF     R  0A25 02597 0B14 02836
     FF      R  0B15 02837 0C04 03076     F       R  0C05 03077 0CF4 03316
     V       R  0CF5 03317 0DE4 03556     VBAR    R  0DE5 03557 0ED4 03796
     VMOM    R  0ED5 03797 0FC4 04036     VENG    R  0FC5 04037 10B4 04276
     FMASS   R  10B5 04277 11A4 04516     RR      R  11A5 04517 1294 04756
     R       R  1295 04757 1384 04996     RT      R  1385 04997 1474 05236
     SC      R  1475 05237 1564 05476     SIGMA   R  1565 05477 1654 05716
     VV      R  1655 05717 1744 05956     CPPP    R  1745 05957 1834 06196
     RTRB    R  1835 06197 1924 06436     CLS     R  1925 06437 1A14 06676
```

THE LOSS COEFFICIENT, K, IS 0.08000

R/RB	V/VREF	A/AB	FMASS	CT	VBAR/VREF	DELV/VREF	CP	VMOM/VREF	VENG/VREF
0.11880	0.43000	0.00000	0.00000	0.10387					
0.12842	0.43613	0.00240	0.00104	0.10397	0.43319	50.43454	3.06011	0.43321	0.43322
0.13805	0.44229	0.00499	0.00218	0.10406	0.43637	24.11546	1.49183	0.43641	0.43643
0.14767	0.44849	0.00777	0.00342	0.10415	0.43963	15.39349	0.97232	0.43971	0.43975
0.15730	0.45476	0.01073	0.00475	0.10424	0.44297	11.06691	0.71478	0.44310	0.44316
0.16692	0.46116	0.01388	0.00620	0.10433	0.44639	8.49567	0.56189	0.44659	0.44668
0.17654	0.46774	0.01722	0.00775	0.10441	0.44991	6.80000	0.46120	0.45019	0.45032
0.18617	0.47458	0.02075	0.00941	0.10450	0.45354	5.60299	0.39026	0.45391	0.45409
0.19579	0.48175	0.02446	0.01118	0.10459	0.45729	4.71637	0.33785	0.45778	0.45802
0.20542	0.48930	0.02836	0.01308	0.10467	0.46118	4.03566	0.29773	0.46181	0.46212
0.21504	0.49723	0.03244	0.01509	0.10476	0.46523	3.49832	0.26619	0.46603	0.46642
0.22466	0.50545	0.03672	0.01724	0.10484	0.46945	3.06472	0.24086	0.47043	0.47092
0.23429	0.51391	0.04118	0.01951	0.10493	0.47381	2.70856	0.22018	0.47502	0.47562
0.24391	0.52251	0.04583	0.02192	0.10501	0.47833	2.41167	0.20306	0.47978	0.48050
0.25354	0.53119	0.05066	0.02447	0.10510	0.48296	2.16114	0.18873	0.48469	0.48555
0.26316	0.53993	0.05568	0.02716	0.10518	0.48772	1.94753	0.17663	0.48974	0.49074
0.27278	0.54878	0.06089	0.02999	0.10527	0.49257	1.76373	0.16633	0.49492	0.49608
0.28241	0.55781	0.06629	0.03298	0.10535	0.49752	1.60429	0.15751	0.50021	0.50154
0.29203	0.56709	0.07187	0.03612	0.10543	0.50257	1.46497	0.14992	0.50564	0.50714
0.30165	0.57667	0.07764	0.03942	0.10552	0.50772	1.34243	0.14335	0.51119	0.51288
0.31128	0.58659	0.08359	0.04288	0.10560	0.51300	1.23399	0.13765	0.51689	0.51879
0.32090	0.59675	0.08974	0.04652	0.10569	0.51839	1.13754	0.13269	0.52275	0.52486
0.33053	0.60707	0.09607	0.05033	0.10577	0.52390	1.05134	0.12838	0.52875	0.53110
0.34015	0.61744	0.10259	0.05432	0.10585	0.52952	0.97400	0.12462	0.53489	0.53749
0.34977	0.62776	0.10929	0.05850	0.10594	0.53523	0.90436	0.12135	0.54116	0.54402
0.35940	0.63796	0.11618	0.06286	0.10602	0.54103	0.84148	0.11851	0.54753	0.55066
0.36902	0.64804	0.12326	0.06741	0.10610	0.54689	0.78452	0.11605	0.55399	0.55739
0.37865	0.65803	0.13053	0.07216	0.10618	0.55280	0.73281	0.11392	0.56051	0.56418
0.38827	0.66796	0.13798	0.07710	0.10627	0.55875	0.68572	0.11209	0.56708	0.57104
0.39789	0.67784	0.14562	0.08224	0.10635	0.56475	0.64274	0.11054	0.57371	0.57794
0.40752	0.68770	0.15345	0.08758	0.10643	0.57077	0.60343	0.10922	0.58037	0.58489
0.41714	0.69752	0.16146	0.09314	0.10652	0.57682	0.56738	0.10812	0.58706	0.59187
0.42677	0.70724	0.16967	0.09890	0.10660	0.58289	0.53425	0.10721	0.59379	0.59887
0.43639	0.71681	0.17805	0.10487	0.10668	0.58898	0.50376	0.10649	0.60053	0.60589
0.44601	0.72619	0.18663	0.11106	0.10677	0.59507	0.47564	0.10593	0.60727	0.61291
0.45564	0.73532	0.19539	0.11746	0.10685	0.60116	0.44968	0.10551	0.61401	0.61992
0.46526	0.74421	0.20434	0.12408	0.10693	0.60723	0.42566	0.10523	0.62072	0.62690
0.47489	0.75290	0.21348	0.13092	0.10701	0.61328	0.40341	0.10508	0.62740	0.63384
0.48451	0.76145	0.22280	0.13798	0.10710	0.61930	0.38278	0.10504	0.63405	0.64073
0.49413	0.76989	0.23231	0.14527	0.10718	0.62530	0.36360	0.10510	0.64065	0.64757
0.50376	0.77827	0.24201	0.15277	0.10726	0.63126	0.34576	0.10526	0.64721	0.65437
0.51338	0.78661	0.25190	0.16051	0.10734	0.63720	0.32913	0.10551	0.65373	0.66111
0.52301	0.79492	0.26197	0.16847	0.10743	0.64310	0.31361	0.10585	0.66021	0.66781
0.53263	0.80319	0.27223	0.17667	0.10751	0.64898	0.29911	0.10627	0.66665	0.67447
0.54225	0.81141	0.28267	0.18510	0.10759	0.65483	0.28553	0.10677	0.67306	0.68109
0.55188	0.81959	0.29331	0.19378	0.10767	0.66066	0.27280	0.10734	0.67944	0.68767
0.56150	0.82773	0.30413	0.20269	0.10776	0.66646	0.26086	0.10798	0.68579	0.69421
0.57113	0.83583	0.31514	0.21184	0.10784	0.67223	0.24965	0.10868	0.69210	0.70072
0.58075	0.84390	0.32633	0.22125	0.10792	0.67799	0.23910	0.10945	0.69838	0.70719
0.59037	0.85195	0.33771	0.23090	0.10800	0.68371	0.22916	0.11029	0.70463	0.71363
0.60000	0.86000	0.34928	0.24080	0.10809	0.68942	0.21980	0.11118	0.71086	0.72005

THE MINIMUM VALUE OF CP IS 0.1050347 THE CORRESPONDING AREA RATIO IS 0.2220265

AND THE MASS FLOW RATE COEFFICIENT IS 0.1373917

THE AREA RATIO IS INCREASED BY 0.00000PERCENT TO THE DESIGN VALUE 0.2220265

CP AND FMASS ARE 0.1050347 AND 0.1373917 RESPECTIVELY

THE ADVANCE RATIO IS 0.67500

RT/RB	SIGMA
0.3484780	2.9489250
0.3785555	2.4214153
0.4064131	2.1573200
0.4324800	2.0341940
0.4570627	1.9933653
0.4803891	2.0038347
0.5026341	2.0479650
0.5239354	2.1151104
0.5444040	2.1985359
0.5641304	2.2938061
0.5831898	2.3979073

May 3, 1979
WSG:JEF:mmj

THE ADVANCE RATIO IS 0.67500

R/RB	CP-NEW	EFF-ROT	EFF-STAT	EFF-TOT	CL-STAT	CL-ROT	S/C-ROT	S/C-STAT	SGMA	RT/RB
0.12842	2.69303	0.99997	0.99998	0.99995	1.40000	0.31223	0.33922	1.37267	0.64343	0.12174
0.13805	1.31315	0.99983	0.99991	0.99974	1.40000	0.31060	0.33349	1.25416	0.75770	0.13325
0.14767	0.85628	0.99951	0.99974	0.99925	1.40000	0.30931	0.32906	1.15595	0.88019	0.14457
0.15730	0.63008	0.99888	0.99942	0.99830	1.40000	0.30827	0.32555	1.07299	1.01089	0.15574
0.16692	0.49610	0.99779	0.99889	0.99669	1.40000	0.30741	0.32271	1.00182	1.14981	0.16681
0.17654	0.40826	0.99604	0.99807	0.99412	1.40000	0.30669	0.32038	0.93999	1.29695	0.17778
0.18617	0.34681	0.99338	0.99684	0.99024	1.40000	0.30608	0.31844	0.88571	1.45231	0.18868
0.19579	0.30194	0.98949	0.99509	0.98464	1.40000	0.30557	0.31680	0.83763	1.61590	0.19951
0.20542	0.26923	0.98401	0.99267	0.97680	1.40000	0.30513	0.31541	0.79470	1.78774	0.21028
0.21504	0.24245	0.97649	0.98941	0.96615	1.40000	0.30475	0.31422	0.75612	1.96782	0.22101
0.22466	0.22264	0.96643	0.98510	0.95202	1.40000	0.30442	0.31320	0.72123	2.15614	0.23171
0.23429	0.20751	0.95324	0.97951	0.93371	1.40000	0.30413	0.31230	0.68952	2.35272	0.24236
0.24391	0.19527	0.93626	0.97241	0.91043	1.40000	0.30388	0.31152	0.66055	2.55754	0.25299
0.25354	0.18843	0.91476	0.96352	0.88139	1.40000	0.30365	0.31083	0.63399	2.77059	0.26359
0.26316	0.18377	0.88795	0.95252	0.84579	1.40000	0.30345	0.31022	0.60953	2.99189	0.27416
0.27278	0.18231	0.85493	0.93911	0.80288	1.40000	0.30327	0.30967	0.58694	3.22142	0.28472
0.28241	0.18432	0.81477	0.92293	0.75198	1.40000	0.30311	0.30918	0.56599	3.45918	0.29526
0.29203	0.19048	0.76545	0.90363	0.69259	1.40000	0.30296	0.30874	0.54652	3.70518	0.30578
0.30165	0.18508	0.74917	0.90978	0.68158	1.40000	0.30310	0.32491	0.58219	3.45967	0.31628
0.31128	0.16904	0.76702	0.93420	0.71656	1.40000	0.30351	0.36216	0.68200	2.87457	0.32677
0.32090	0.15754	0.78065	0.94945	0.74120	1.40000	0.30388	0.40497	0.79274	2.46291	0.33725
0.33053	0.14880	0.79133	0.95939	0.75920	1.40000	0.30421	0.45378	0.91489	2.17043	0.34772
0.34015	0.14190	0.79994	0.96613	0.77284	1.40000	0.30450	0.50907	1.04888	1.96164	0.35818
0.34977	0.13628	0.80707	0.97088	0.78357	1.40000	0.30475	0.57130	1.19508	1.81282	0.36863
0.35940	0.13162	0.81319	0.97436	0.79234	1.40000	0.30496	0.64090	1.35381	1.70777	0.37907
0.36902	0.12769	0.81860	0.97701	0.79978	1.40000	0.30512	0.71834	1.52532	1.63527	0.38950
0.37865	0.12432	0.82358	0.97909	0.80636	1.40000	0.30526	0.80404	1.70985	1.58740	0.39993
0.38827	0.12143	0.82829	0.98079	0.81238	1.40000	0.30536	0.89844	1.90759	1.55847	0.41035
0.39789	0.11883	0.83290	0.98279	0.81856	1.32157	0.30543	1.00197	2.00000	1.54437	0.42076
0.40752	0.11653	0.83752	0.98480	0.82479	1.19489	0.30548	1.11506	2.00000	1.54206	0.43116
0.41714	0.11452	0.84226	0.98640	0.83080	1.08463	0.30551	1.23813	2.00000	1.54928	0.44157
0.42677	0.11276	0.84720	0.98768	0.83676	0.98821	0.30552	1.37159	2.00000	1.56432	0.45196
0.43639	0.11119	0.85240	0.98872	0.84278	0.90353	0.30552	1.51581	2.00000	1.58588	0.46235
0.44601	0.10980	0.85792	0.98957	0.84897	0.82885	0.30551	1.67117	2.00000	1.61295	0.47274
0.45564	0.10901	0.86013	0.99027	0.85176	0.76273	0.29917	1.80000	2.00000	1.64474	0.48312
0.46526	0.11010	0.84889	0.99084	0.84111	0.70398	0.27264	1.80000	2.00000	1.68065	0.49350
0.47489	0.11151	0.83650	0.99131	0.82923	0.65160	0.24904	1.80000	2.00000	1.72016	0.50388
0.48451	0.11326	0.82296	0.99169	0.81612	0.60472	0.22800	1.80000	2.00000	1.76288	0.51425
0.49413	0.11535	0.80824	0.99201	0.80178	0.56264	0.[illegible]922	1.80000	2.00000	1.80850	0.52462
0.50376	0.11782	0.79231	0.99226	0.78618	0.52474	0.19239	1.80000	2.00000	1.85674	0.53499
0.51338	0.12069	0.77517	0.99246	0.76933	0.49051	0.17730	1.80000	2.00000	1.90740	0.54535
0.52301	0.12400	0.75677	0.99262	0.75119	0.45951	0.16373	1.80000	2.00000	1.96030	0.55571
0.53263	0.12780	0.73710	0.99274	0.73175	0.43134	0.15149	1.80000	2.00000	2.01529	0.56607
0.54225	0.13215	0.71612	0.99283	0.71098	0.40569	0.14044	1.80000	2.00000	2.07224	0.57643
0.55188	0.13712	0.69380	0.99289	0.68887	0.38228	0.13044	1.80000	2.00000	2.13105	0.58678
0.56150	0.14280	0.67013	0.99292	0.66538	0.36085	0.12137	1.80000	2.00000	2.19164	0.59713
0.57113	0.14932	0.64506	0.99294	0.64050	0.34120	0.11313	1.80000	2.00000	2.25393	0.60748
0.58075	0.15682	0.61858	0.99293	0.61421	0.32315	0.10562	1.80000	2.00000	2.31786	0.61783
0.59037	0.16549	0.59065	0.99291	0.58647	0.30652	0.09878	1.80000	2.00000	2.38337	0.62817
0.60000	0.17558	0.56126	0.99287	0.55726	0.29118	0.09252	1.80000	2.00000	2.45041	0.63852

THE ADVANCE RATIO IS 0.84400

RT/RB	SIGMA
0.3484780	2.7327461
0.3785555	2.1436138
0.4064131	1.8206558
0.4324800	1.6404524
0.4570627	1.5437746
0.4803891	1.4992752
0.5026341	1.4890871
0.5239354	1.5024080
0.5444040	1.5323944
0.5641304	1.5745325
0.5831898	1.6257486

THE ADVANCE RATIO IS 0.84400

R/RB	CP-NEW	EFF-ROT	EFF-STAT	EFF-TOT	CL-STAT	CL-ROT	S/C-ROT	S/C-STAT	SGMA	RT/RB
0.12842	2.69298	0.99998	0.99999	0.99997	1.40000	0.31760	0.35961	1.71634	0.43725	0.12174
0.13805	1.31302	0.99990	0.99994	0.99984	1.40000	0.31543	0.35109	1.56817	0.51072	0.13325
0.14767	0.85603	0.99972	0.99983	0.99955	1.40000	0.31367	0.34446	1.44537	0.58946	0.14457
0.15730	0.62964	0.99936	0.99963	0.99899	1.40000	0.31221	0.33918	1.34163	0.67346	0.15574
0.16692	0.49542	0.99875	0.99931	0.99806	1.40000	0.31101	0.33490	1.25264	0.76273	0.16681
0.17654	0.40725	0.99778	0.99881	0.99659	1.40000	0.30999	0.33136	1.17534	0.85728	0.17778
0.18617	0.34536	0.99631	0.99808	0.99440	1.40000	0.30912	0.32842	1.10747	0.95710	0.18868
0.19579	0.29993	0.99418	0.99706	0.99126	1.40000	0.30838	0.32593	1.04734	1.06220	0.19951
0.20542	0.26548	0.99119	0.99566	0.98689	1.40000	0.30774	0.32381	0.99367	1.17260	0.21028
0.21504	0.23878	0.98712	0.99381	0.98100	1.40000	0.30719	0.32199	0.94542	1.28830	0.22101
0.22466	0.21779	0.98168	0.99139	0.97323	1.40000	0.30670	0.32042	0.90180	1.40929	0.23171
0.23429	0.20116	0.97458	0.98830	0.96318	1.40000	0.30628	0.31905	0.86215	1.53559	0.24236
0.24391	0.18801	0.96547	0.98441	0.95041	1.40000	0.30590	0.31785	0.82594	1.66719	0.25299
0.25354	0.17773	0.95397	0.97958	0.93449	1.40000	0.30557	0.31679	0.79272	1.80407	0.26359
0.26316	0.16989	0.93965	0.97367	0.91491	1.40000	0.30527	0.31584	0.76214	1.94625	0.27416
0.27278	0.16424	0.92207	0.96652	0.89120	1.40000	0.30500	0.31500	0.73389	2.09372	0.28472
0.28241	0.16064	0.90071	0.95798	0.86286	1.40000	0.30476	0.31425	0.70770	2.24646	0.29526
0.29203	0.15905	0.87507	0.94785	0.82944	1.40000	0.30454	0.31357	0.68335	2.40450	0.30578
0.30165	0.15958	0.84457	0.93598	0.79050	1.40000	0.30434	0.31296	0.66065	2.56783	0.31628
0.31128	0.16244	0.80861	0.92216	0.74567	1.40000	0.30416	0.31240	0.63944	2.73646	0.32677
0.32090	0.16531	0.77468	0.91181	0.70636	1.40000	0.30409	0.31580	0.63400	2.81825	0.33725
0.33053	0.15334	0.79007	0.93247	0.73672	1.40000	0.30460	0.34789	0.73170	2.36985	0.34772
0.34015	0.14452	0.80208	0.94604	0.75880	1.40000	0.30508	0.38427	0.83886	2.04451	0.35818
0.34977	0.13773	0.81164	0.95529	0.77535	1.40000	0.30551	0.42524	0.95578	1.80634	0.36863
0.35940	0.13232	0.81942	0.96181	0.78813	1.40000	0.30590	0.47111	1.08272	1.63101	0.37907
0.36902	0.12792	0.82590	0.96658	0.79830	1.40000	0.30625	0.52214	1.21989	1.50174	0.38950
0.37865	0.12428	0.83143	0.97017	0.80663	1.40000	0.30655	0.57861	1.36748	1.40675	0.39993
0.38827	0.12123	0.83627	0.97297	0.81366	1.40000	0.30680	0.64082	1.52562	1.33769	0.41035
0.39789	0.11866	0.84061	0.97522	0.81978	1.40000	0.30701	0.70903	1.69446	1.28849	0.42076
0.40752	0.11646	0.84452	0.97708	0.82526	1.40000	0.30718	0.78351	1.87409	1.25477	0.43116
0.41714	0.11454	0.84841	0.97906	0.83064	1.35619	0.30731	0.86453	2.00000	1.23326	0.44157
0.42677	0.11283	0.85208	0.98137	0.83621	1.23563	0.30742	0.95235	2.00000	1.22153	0.45196
0.43639	0.11138	0.85571	0.98324	0.84137	1.12974	0.30750	1.04721	2.00000	1.21773	0.46235
0.44601	0.11015	0.85937	0.98476	0.84627	1.03637	0.30755	1.14935	2.00000	1.22046	0.47274
0.45564	0.10910	0.86310	0.98602	0.85103	0.95370	0.30759	1.25900	2.00000	1.22861	0.48312
0.46526	0.10822	0.86695	0.98706	0.85573	0.88024	0.30761	1.37635	2.00000	1.24134	0.49350
0.47489	0.10747	0.87095	0.98792	0.86043	0.81474	0.30761	1.50163	2.00000	1.25797	0.50388
0.48451	0.10683	0.87515	0.98864	0.86521	0.75612	0.30760	1.63504	2.00000	1.27796	0.51425
0.49413	0.10629	0.87956	0.98925	0.87010	0.70351	0.30758	1.77678	2.00000	1.30090	0.52462
0.50376	0.10714	0.87347	0.98975	0.86452	0.65612	0.28727	1.80000	2.00000	1.32642	0.53499
0.51338	0.10844	0.86471	0.99018	0.85622	0.61332	0.26535	1.80000	2.00000	1.35425	0.54535
0.52301	0.10996	0.85523	0.99053	0.84713	0.57455	0.24555	1.80000	2.00000	1.38415	0.55571
0.53263	0.11169	0.84502	0.99082	0.83727	0.53933	0.22764	1.80000	2.00000	1.41595	0.56607
0.54225	0.11366	0.83407	0.99106	0.82661	0.50726	0.21140	1.80000	2.00000	1.44947	0.57643
0.55188	0.11587	0.82237	0.99126	0.81518	0.47799	0.19667	1.80000	2.00000	1.48460	0.58678
0.56150	0.11834	0.80991	0.99142	0.80295	0.45120	0.18326	1.80000	2.00000	1.52121	0.59713
0.57113	0.12107	0.79668	0.99154	0.78994	0.42663	0.17105	1.80000	2.00000	1.55922	0.60748
0.58075	0.12410	0.78267	0.99163	0.77612	0.40406	0.15990	1.80000	2.00000	1.59854	0.61783
0.59037	0.12745	0.76787	0.99170	0.76150	0.38327	0.14971	1.80000	2.00000	1.63912	0.62817
0.60000	0.13115	0.75227	0.99175	0.74606	0.36409	0.14038	1.80000	2.00000	1.68089	0.63852

THE ADVANCE RATIO IS 1.12500

RT/RB	SIGMA
0.3484780	2.6591120
0.3785555	2.0078077
0.4064131	1.6286163
0.4324800	1.3960419
0.4570627	1.2496357
0.4803891	1.1573019
0.5026341	1.1006804
0.5239354	1.0686359
0.5444040	1.0540876
0.5641304	1.0523520
0.5831898	1.0602245

THE ADVANCE RATIO IS 1.12500

R/RB	CP-NEW	EFF-ROT	EFF-STAT	EFF-TOT	CL-STAT	CL-ROT	S/C-ROT	S/C-STAT	SGMA	RT/RB
0.12842	2.69294	0.99999	0.99999	0.99998	1.22389	0.32671	0.40028	2.00000	0.27727	0.12174
0.13805	1.31293	0.99995	0.99996	0.99991	1.33954	0.32384	0.38651	2.00000	0.31908	0.13325
0.14767	0.85585	0.99985	0.99990	0.99975	1.40000	0.32144	0.37568	1.92659	0.36387	0.14457
0.15730	0.62936	0.99967	0.99978	0.99945	1.40000	0.31940	0.36699	1.78831	0.41164	0.15574
0.16692	0.49493	0.99936	0.99959	0.99895	1.40000	0.31767	0.35988	1.66970	0.46239	0.16681
0.17654	0.40659	0.99888	0.99930	0.99819	1.40000	0.31618	0.35399	1.56665	0.51613	0.17778
0.18617	0.34444	0.99817	0.99890	0.99706	1.40000	0.31489	0.34904	1.47619	0.57286	0.18368
0.19579	0.29865	0.99714	0.99833	0.99548	1.40000	0.31377	0.34485	1.39605	0.63258	0.19951
0.20542	0.26377	0.99571	0.99758	0.99330	1.40000	0.31279	0.34127	1.32450	0.69531	0.21028
0.21504	0.23652	0.99378	0.99659	0.99039	1.40000	0.31194	0.33818	1.26019	0.76105	0.22101
0.22466	0.21484	0.99122	0.99531	0.98658	1.40000	0.31118	0.33551	1.20205	0.82981	0.23171
0.23429	0.19737	0.98790	0.99371	0.98169	1.40000	0.31051	0.33317	1.14919	0.90158	0.24236
0.24391	0.18317	0.98367	0.99172	0.97552	1.40000	0.30992	0.33111	1.10092	0.97636	0.25299
0.25354	0.17160	0.97835	0.98928	0.96786	1.40000	0.30938	0.32930	1.05665	1.05414	0.26359
0.26316	0.16217	0.97176	0.98633	0.95848	1.40000	0.30890	0.32768	1.01589	1.13493	0.27416
0.27278	0.15454	0.96370	0.98280	0.94713	1.40000	0.30847	0.32623	0.97823	1.21872	0.28472
0.28241	0.14847	0.95395	0.97863	0.93357	1.40000	0.30808	0.32493	0.94332	1.30550	0.29526
0.29203	0.14378	0.94228	0.97374	0.91753	1.40000	0.30773	0.32376	0.91086	1.39529	0.30578
0.30165	0.14035	0.92844	0.96805	0.89878	1.40000	0.30740	0.32270	0.88061	1.48808	0.31628
0.31128	0.13811	0.91216	0.96150	0.87705	1.40000	0.30711	0.32174	0.85233	1.58389	0.32677
0.32090	0.13703	0.89319	0.95400	0.85211	1.40000	0.30684	0.32087	0.82585	1.68270	0.33725
0.33053	0.13714	0.87124	0.94549	0.82375	1.40000	0.30659	0.32007	0.80099	1.78453	0.34772
0.34015	0.13851	0.84602	0.93587	0.79177	1.40000	0.30637	0.31934	0.77760	1.88937	0.35818
0.34977	0.14125	0.81723	0.92509	0.75602	1.40000	0.30616	0.31868	0.75556	1.99721	0.36863
0.35940	0.13753	0.81447	0.93103	0.75829	1.40000	0.30653	0.33675	0.81228	1.84156	0.37907
0.36902	0.13149	0.82434	0.94217	0.77667	1.40000	0.30716	0.36696	0.91519	1.61092	0.38950
0.37865	0.12675	0.83239	0.95021	0.79094	1.40000	0.30775	0.40045	1.02591	1.43593	0.39993
0.38827	0.12295	0.83906	0.95619	0.80230	1.40000	0.30829	0.43737	1.14455	1.30242	0.41035
0.39789	0.11986	0.34470	0.96076	0.81155	1.40000	0.30878	0.47788	1.27122	1.20024	0.42076
0.40752	0.11732	0.84954	0.96435	0.81925	1.40000	0.30922	0.52213	1.40598	1.12202	0.43116
0.41714	0.11521	0.85378	0.96724	0.82581	1.40000	0.30960	0.57026	1.54891	1.06235	0.44157
0.42677	0.11347	0.85756	0.96964	0.83152	1.40000	0.30994	0.62242	1.70004	1.01723	0.45196
0.43639	0.11202	0.86099	0.97166	0.83659	1.40000	0.31023	0.67875	1.85938	0.98364	0.46235
0.44601	0.11079	0.86416	0.97362	0.84136	1.38141	0.31047	0.73937	2.00000	0.95930	0.47274
0.45564	0.10968	0.86714	0.97628	0.84657	1.27122	0.31067	0.80441	2.00000	0.94246	0.48312
0.46526	0.10879	0.86999	0.97847	0.85126	1.17330	0.31084	0.87399	2.00000	0.93177	0.49350
0.47489	0.10808	0.87276	0.98029	0.85556	1.08599	0.31098	0.94820	2.00000	0.92616	0.50388
0.48451	0.10753	0.87549	0.98182	0.85957	1.00787	0.31108	1.02718	2.00000	0.92480	0.51425
0.49413	0.10712	0.87820	0.98311	0.86337	0.93773	0.31116	1.11102	2.00000	0.92703	0.52462
0.50376	0.10683	0.88094	0.98421	0.86702	0.87457	0.31122	1.19983	2.00000	0.93232	0.53499
0.51338	0.10665	0.88371	0.98514	0.87058	0.81752	0.31125	1.29372	2.00000	0.94024	0.54535
0.52301	0.10657	0.88655	0.98594	0.87408	0.76584	0.31127	1.39278	2.00000	0.95045	0.55571
0.53263	0.10656	0.88948	0.98662	0.87757	0.71890	0.31127	1.49713	2.00000	0.96267	0.56607
0.54225	0.10664	0.89250	0.98720	0.88107	0.67615	0.31126	1.60684	2.00000	0.97666	0.57643
0.55188	0.10678	0.89563	0.98770	0.88462	0.63713	0.31124	1.72201	2.00000	0.99224	0.58678
0.56150	0.10734	0.89584	0.98813	0.88520	0.60142	0.30400	1.80000	2.00000	1.00924	0.59713
0.57113	0.10870	0.89011	0.98850	0.87987	0.56867	0.28446	1.80000	2.00000	1.02754	0.60748
0.58075	0.11020	0.88398	0.98881	0.87409	0.53858	0.26655	1.80000	2.00000	1.04702	0.61783
0.59037	0.11183	0.87745	0.98907	0.86786	0.51087	0.25011	1.80000	2.00000	1.06758	0.62817
0.60000	0.11361	0.87052	0.98930	0.86120	0.48531	0.23499	1.80000	2.00000	1.08916	0.63852

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